LEiSEGANG

LM-90 ELECTROSURGICAL GENERATOR

SERVICE MANUAL

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1. MASTER THEORY OF OPERATIONS

1.1 Introduction

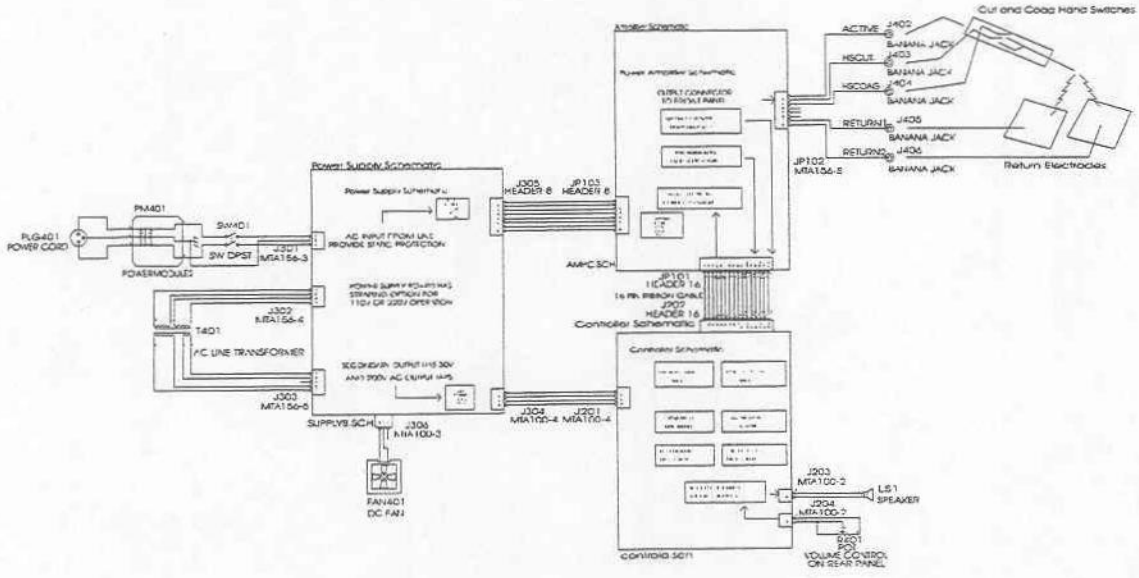
This document describes a theory of operation for the complete system of the LM90 ESU. Each of the three circuit board assemblies are described in brevity. For a detailed explanation refer to the individual theory of operation for each board.

1.2 System Overview

The LM90 is an electrosurgical unit designed to convert an AC line source of 110/120V or 220/240V, at 50Hz or 60Hz, to a modulated 450KHz output. The operating modes and power levels are set by controls on the front panel. The output power settings are displayed on the front panel as 0 to 120 Watts Cut (including Blend1 and Blend2), and 0 to 80 Watts Coag, into the 300Ω Rated Load. All outputs are disabled below a 10 Watt set point, that is, they will display '0' and produce no output. There are five modes of operation:

Mode	Output Type	Wave form	Output Adjustment
CUT	continuous 50% duty cycle	-	0 to 120 Watts
BLEND1	bursts of 50% duty cycle	8 pulses out of 16	0 to 120 Watts
BLEND2	bursts of 37.5% duty cycle	6 pulses out of 16	0 to 120 Watts
COAG1	bursts of 18.75% duty cycle	3 pulses out of 16	0 to 80 Watts
COAG2	bursts of 12.5% duty cycle	2 pulses out of 16	0 to 80 Watts

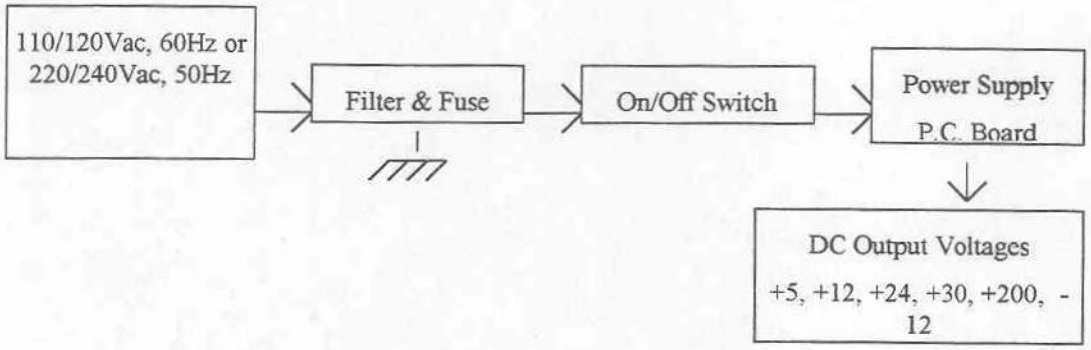
1.3 Block Diagram



1.4 Circuit Functions

1.4.1 AC Input Filtering

The line voltage is initially filtered and fused (both sides of the line) by an input module specifically designed for medical equipment. The voltage is than sent to the front panel on/off switch which provides power to the primary side of the 60Hz transformer. As well as providing the proper unregulated secondary voltages, the 60Hz transformer serves as an isolation barrier separating the user and patient from the a.c. mains.



1.4.2 Power Supply Board

This circuit board provides all of the regulated and unregulated voltages necessary for the LM90 electronics. Power supplies are developed as follows:

Description	Source	Regulation Type
+200V	bridge rectified from 60Hz transformer	unregulated
+30V	bridge rectified from 60Hz transformer	unregulated
+24V	+30Vdc	linear
+12V/-12V	+30Vdc	switch mode
+5V	+30Vdc	switch mode

Description	Where Used
+200 Vdc	Power amplifier -- output power supply
+30 Vdc	Power amplifier -- relays
+24Vdc	Fan
+12/-12 Vdc	All boards -- supplies
+5 Vdc	Controller -- +5V logic levels

1.4.2.1 Connectors

All connections to the power supply board are made with multi-stranded wire. Some cables are bundled, refer to LM-90 cable drawings for details.

J301 connects to power switch

Designator	Description	Comment
J301-1	50/60Hz primary	From power switch
J301-2	Chassis ground	-
J301-3	50/60Hz primary	From power switch

J302 connects to primary of 50/60Hz AC transformer

Designator	Description	Comment
J302-1	50/60Hz AC input	To power transformer primary
J302-2	Jumper select	For 110/120 or 220/240 operation
J303-3	Jumper select	For 110/120 or 220/240 operation
J304-4	50/60Hz AC input	To power transformer primary

J303 connects to secondary of 50/60Hz AC transformer

Designator	Description	Comment
J303-1	50/60Hz Secondary	For +30 Vdc
J303-2	50/60Hz Secondary	For +30 Vdc
J303-3	No connection	-
J303-4	50/60Hz Secondary	For +200 Vdc
J303-5	50/60Hz Secondary	For +200 Vdc

J304 connects to controller board J201

Designator	Description	Comment
J304-1	-5V	-5 Vdc supply
J304-2	Ground	Circuit common
J304-3	+12V	+12Vdc supply
J304-4	-12V	-12Vdc supply

J305 connects to power amplifier JP103

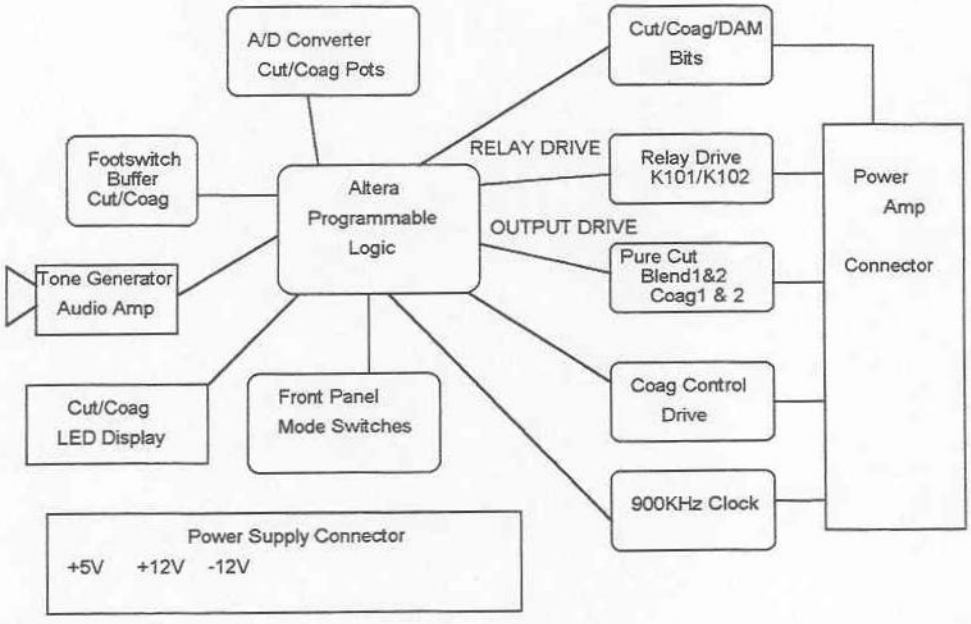
Designator	Description	Comment
J305-1, J305-2	+200V	+200 Vdc -- output supply
J305-3, J305-4	Ground	Circuit common
J305-5	+12V	+12 Vdc supply
J305-6	+30V	+30 Vdc for relays
J305-7	-12V	-12 Vdc supply
J305-8	No connection	Spare

J306 connects to fan

Designator	Description	Comment
J306-1	+24V	+24Vdc for fan
J306-2	Ground	Ground for fan
J306-3	No connection	-

1.4.3 Controller Board

The controller board provides the user interface for all of the ESU functions: Output Modes: Cut, Blend1, Blend2, Coag1, and Coag2; as well as, power set point adjustments, volume control, and the LED displays.



1.4.3.1 LED Display

The LED display provides visual feedback regarding power setting. There are three seven segment displays for the Cut modes and two seven segment displays for the Coag modes. Output range settings are adjustable

from 0 to 120 for Cut modes and 0 to 80 for Coag modes. These displays are controlled and multiplexed by an EPLD mounted on the controller board.

1.4.3.2 Potentiometers/switches

When the Cut or Coag mode is selected, the center tap of the pot is sent to an A/D converter and to a buffered output. The A/D converter is used by the EPLD to provide the correlating numeric representation on the LED display. The buffered output is sent to the power amplifier for set-point control. A precise voltage reference is used as a reference for the A/D converter to eliminate the fluctuations which are present on the power supplies.

1.4.3.3 Hand Switch/Foot Switch

When either the Cut or the Coag button on the hand switch is pressed a low-noise signal is sent from the power amplifier to the controller board. This signal is recovered on the controller board by a Schmitt trigger (sch-IHSCUT or ISHCOAG). The EPLD then processes the signal and selects the proper output controls for the power amplifier circuit. For instance, when the Coag button is selected, two relay control signals are sent to the power amplifier (sch-K101DRV and K102DRV). One selects the appropriate tap on the output transformer, and the other controls the amount of signal sent to the power amplifier. Since 80 watts is 2/3 of 120 watts, a relay is used in conjunction with a resistive network to ensure that the input signal does not allow more than 80 watts output when in Coag mode. This remaining control current is sent to ground.

The foot switch perform the same functions except that the input to the controller is provide by optoisolators (sch-COAGFS and CUTFS).

1.4.3.4 LED Indicators

The controller monitors four different LED indicators as shown:

Indicator	Comment
Blue LED on	unit is operating in Coag mode
Amber LED on	unit is operating in Cut mode
Red LED on	an error has occurred
Green LED on	unit is on

The blue LED lights when the Coag hand or footswitch is pressed. This indicates that the system is working properly and that Coag power is being applied.

The amber LED lights when the Cut hand or foot switch is pressed. This indicates that the system is working properly and that Cut power is being applied.

The red LED is an alarm indicator. When this is on, an error has occurred and the controller will no longer apply power. This error occurs when any two switches are pressed at the same time or the dispersive alarm monitor (DAM) circuit reports and error (sch-ELEMON). In addition to the red LED, an audio alarm will also sound.

The green LED simply monitors the +5V supply on the controller. This indicates that the unit is on.

1.4.3.5 Master Clock

A 900kHz square wave signal is sent from the power amplifier to the controller card(sch-MASTERCLK). This signal is buffered by a Schmitt trigger for input to the EPLD (sch-SYSCLK).

1.4.3.6 Duty Cycle Control

As mentioned above in *2. System Overview* the output duty cycle is controlled by the controller board. Since the EPLD is synchronized to the switcher on the power amplifier that controls the output, it is possible to precisely control the number of pulses that will appear on the output. The EPLD monitors the front panel switch settings and sends a pulse to the power amplifier allowing the output to pulse the appropriate number times (sch-DUTYCYCLE).

1.4.3.7 Audio

An audio section made up of a tone generator, an amplifier, and a speaker, have been incorporated to enhance use. The audio section informs the user with three different sounds. The Cut modes have a distinctively different pitch than the Coag modes. In normal operating mode, the volume is adjustable. During an alarm condition, the output volume goes to maximum to insure user awareness.

1.4.3.8 Connectors

J201 connects to the power supply board via a bundled multi-stranded cable.

Designator	Label	Description
J201-1	-	+5 Vdc supply
J201-2	-	Ground
J201-3	-	+12 Vdc supply
J201-4	-	-12 Vdc supply

J203-1	-	Speaker (+)
J203-2	-	Speaker (-)

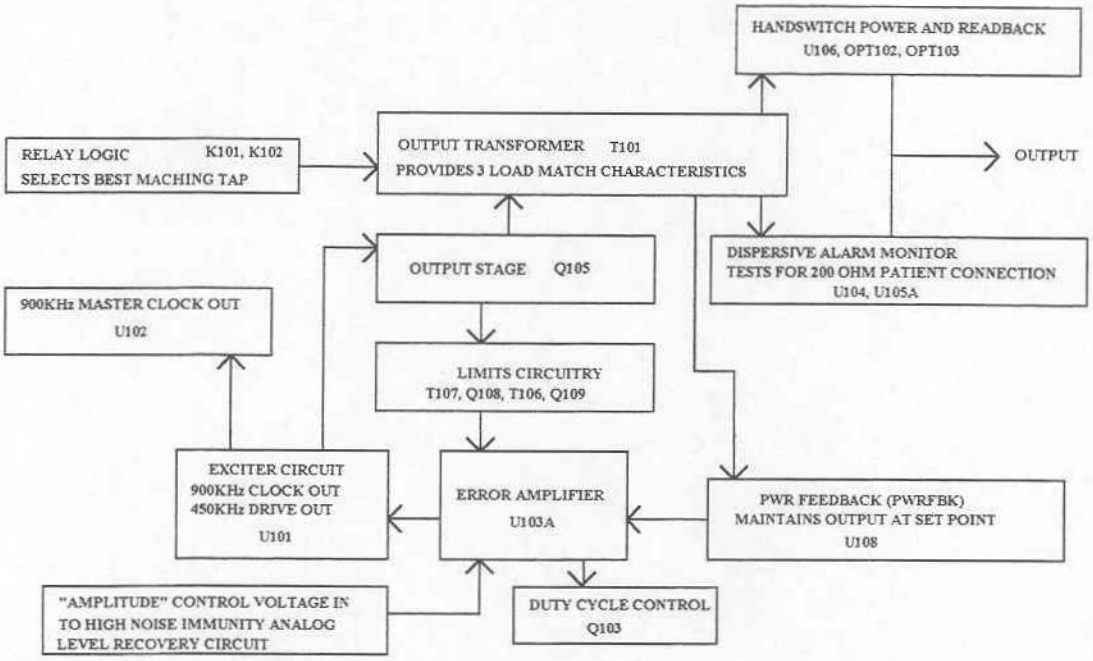
J204-1	-	Volume (+)
J204-2	-	Volume (-)

Refer to section *4.4.10 Connectors* for pin out of J202.

1.4.4 Power Amplifier Board

Under control of the controller board, the amplifier board provides the appropriate output power to the load. The following diagram shows the overall functions of the amplifier board.

1.4.4.1 Power Amplifier Block Diagram



1.4.4.2 Master Clock

A 3825 switching regulator U101, is used as the master clock. The frequency is set at 900kHz by a simple RC network. This clock output is buffered and sent to the controller card to synchronize logic operations. Since only one of the outputs of the 3825 is used, the output drive frequency is 450kHz, 1/2 the 900kHz clock signal. The clock signal is sent to the controller by JP101-7 (sch-MASTRCLK).

1.4.4.3 Output Regulation

Output control is maintained by a closed loop, constant power feedback system. The controller board sends a 0 to 10 mA signal proportional to the desired output wattage. The current arrives at pin JP101-15 (sch-AMPLITUDE). This signal is then inverted, and sent to a virtual ground integrator U103B. Feedback to this virtual ground is provided by a multiplier, U108. When the integral of these two signals are equal in magnitude but opposite in polarity, the system is balance and in regulation. The output duty cycle of the switcher varies to control the output power delivered to the load.

1.4.4.4 Output Waveform Control

When in any mode except Cut, which is a continuous output, the output is in burst mode. The number of pulses in this burst is determined by the controller cards Cut/Coag switches. This signal arrives at JP101-6 (sch-DUTYCYCLE).

1.4.4.5 Relay Control

Pins JP101-3 and JP101-4, K101DRV and K102DRV, respectively, are relay control signals. The controller selects the most appropriate tap on the output transformer T101 depending on the Cut/Coag switches.

1.4.4.6 Isolated Cut/Coag Switches

To reduce the number of wires to the surgical instrument, the active electrode is used as a return path for the isolated Cut/Coag switches. A separate isolated power supply comprising U104, U106, T104 and supporting circuitry provides approximately 12V to power two optoisolators, OPT102 and OPT103. These isolators send 12V logic signals to the controller when a switch is closed. The signals are found at JP101-1(IHSCUT) and JP101-2(IHSCOAG).

1.4.4.7 Dispersive Alarm Monitor (DAM)

The DAM circuit insures proper return electrode connections to the patient. Anything below 200 ohms is considered a proper connection. 200 ohms and above indicates a poor connection which sends a signal to the controller via JP101-3 (ELEMON).

The DAM circuit is comprised of an oscillator, U104 and a resonate tank circuit T103, C111, and C112. When the tank is resonating, a low voltage signal is present at the non-inverting input of the comparator, U105A holding the output low. When the two return electrodes are connected to the patient, the resonate circuit can no longer resonate and the output of the comparator goes high (sch-EMON). This signal is sent to an optoisolator (OPT104B) and converted to a 12V logic level for the controller, JP101-3.

1.4.4.8 Coag Current Divider

The input set-point current is approximately 0 to 10mA for 0 to 120 watt output power into the rated load. Since are maximum output for the Coag modes is 80 watts, the 10mA needs to be scaled down to 2/3 of 10mA or 6.67mA. This is accomplished by K103, R155, and R116. The controller sends a signal via JP101-9 (COAG). When high relay is not engaged and output is set for Cut/Blend modes. When low, output is set for Coag modes.

1.4.4.9 Exciter Circuit Enable

There can be no output from the power amplifier until the controller sends a logic high to JP101-12 (ENABLE). This engages the soft start feature of the switcher, U101, and allows the output pulse width to ramp up in a controlled fashion.

1.4.4.10 Connectors

JP101 mates with J202 on the controller board via a 16 position ribbon cable. Signals are low-power analog and logic levels.

Designator	Label	Description
JP101-1	IHSCUT	From cut switch on instrument
JP101-2	IHSCOAG	From coag switch on instrument
JP101-3	ELEMON	DAM output
JP101-4	K101DRV	Load match relay drive
JP101-5	K102DRV	Load match relay drive
JP101-6	DUTYCYCLE	Burst control
JP101-7	MASTERCLK	System clock
JP101-8	-	No connection
JP101-9	COAG	Max Coag divider
JP101-10	-	No connection
JP101-11	-	No connection
JP101-12	ENABLE	Enables output
JP101-13	-	No connection
JP101-14	-	Ground
JP101-15	AMPLITUDE	Set point amplitude

JP102 serves as a high voltage connector for the outputs of the power amplifier. These connections go to the front panel via bundled, high voltage and multi-stranded wire. Signals are high power and logic level.

Designator	Label	Description
JP102-1	ACTIVELE	Active electrode and Cut/Coag (-)
JP102-2	HSCUT	Cut switch (+)
JP102-3,	HSCOAG	Coag switch (+)
JP102-4, JP102-5, JP102-6	-	No connection
JP102-7	RETURN1	Patient return 1
JP102-8	RETURN2	Patient return 2

1.4.4.11 Power Supply Connections

JP103 is a pin header for all of the power supply connections.

This connector mates with J305 via bundled multi-stranded wire, on the power supply board.

Designator	Comment	Description
JP103-1, JP103-2	+200Vdc	DC supply for output transformer
JP103-3, JP103-4, JP103-8	Power ground	Circuit common
JP103-5	+12Vdc	Power supply (+)
JP103-6	+30Vdc	Relay drive
JP103-7	-12Vdc	Power supply (-)

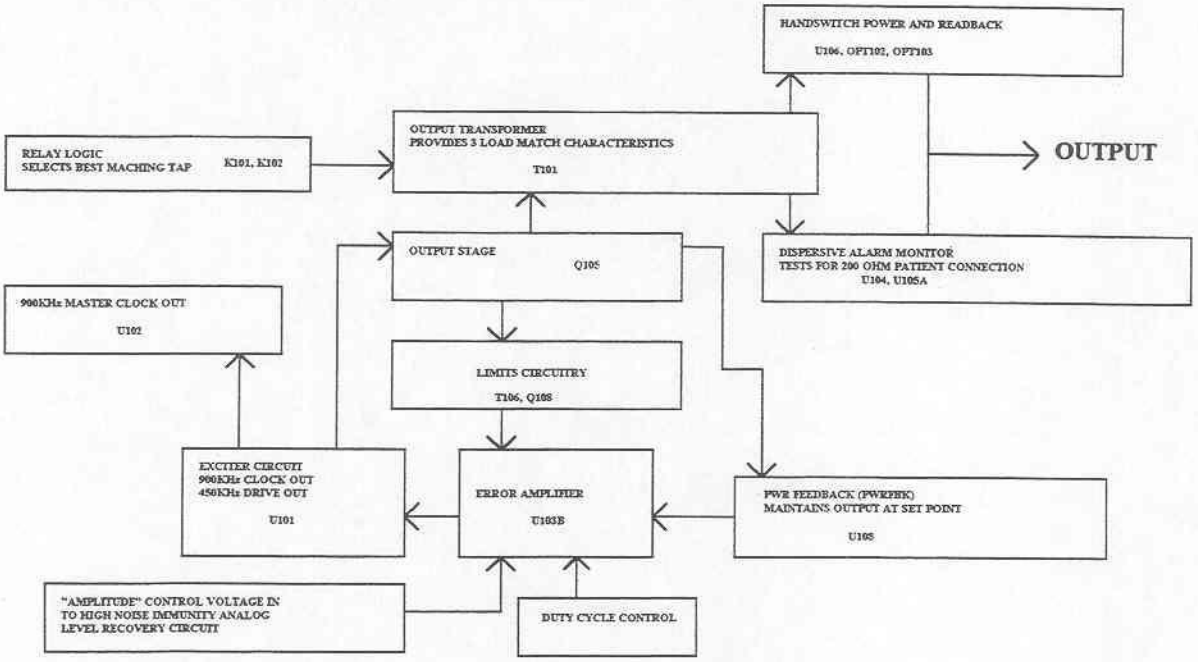
2. Power Amplifier Theory of Operation

2.1 Introduction

This document describes the theory of operation for the power amplifier card for the LM90 ESU. It is a technical document and its intended audience is all manufacturing/test engineering personnel.

2.2 Block Diagram

The LM90 power amplifier board produces 450kHz output at up to 120 watt levels and 1500V peak depending on mode setting. The LM90 incorporates true power control. The ERROR AMPLIFIER compares set point levels of power from the AMPLITUDE control block with PWR FEEDBACK measurements from the output, generating a correcting signal to the EXCITER CIRCUIT.



The EXCITER CIRCUIT provides drive signals to the output stage. The drive adjusts conduction time of the OUTPUT STAGE from zero to 45% of the 450kHz operating frequency, zero to 1 microsecond, modulating the output power level in response to the ERROR AMPLIFIER.

The OUTPUT STAGE switches the 200V supply rail into the OUTPUT TRANSFORMER windings. RELAY LOGIC selects an optimum transformer tap for best load match in a given mode. Four quadrant operation of the output stage and optimized load matching result in high efficiency operation, low temperature rise and low device stresses. LIMITS circuitry also applies bounds to the circuit voltage and current values preventing damage and reducing nuisance fuse clearings.

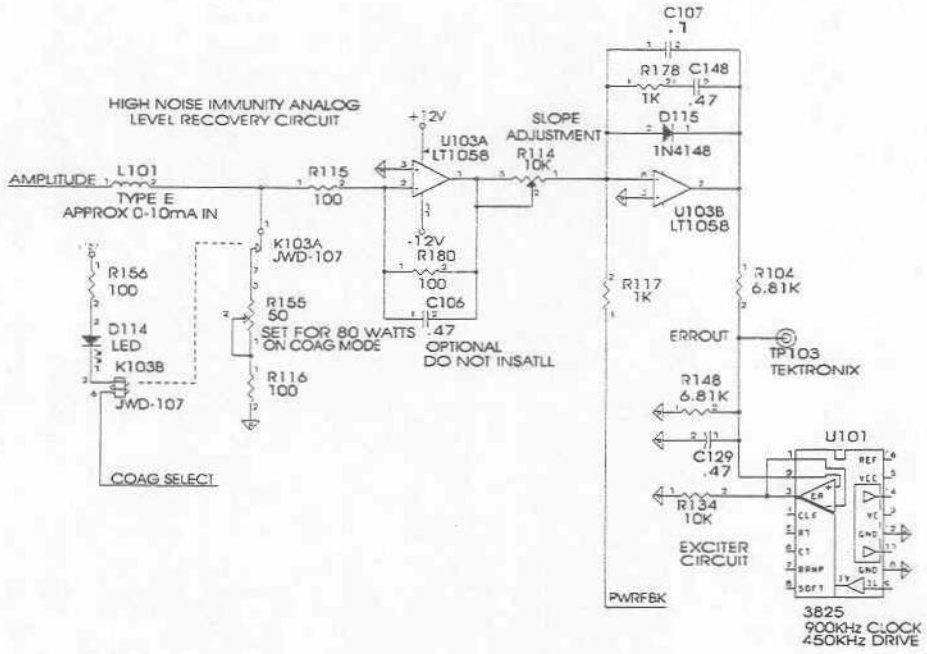
HANDSWITCH POWER AND READBACK circuits employ opto isolated logic circuits to enable CUT and COAG outputs from hand tool buttons. The DISPERSIVE ALARM MONITOR tests for less than 200 ohms of resistance between split patient return electrodes.

The 900kHz MASTER CLOCK OUT is the signal which synchronizes all of the various operating modes and outputs.

DUTY CYCLE CONTROL controls the output wave form type. Wave forms may be continuous as in CUT mode or bursts as in COAG.

2.3 Error Amplifier

The output of the LM90 ESU is regulated in power units: e.g., 40 watts indicated in the digital display delivers 40 watts to the specified load. Load power is varied by adjusting the duty cycle of the exciter output. The exciter IC, a generic 3825 switchmode regulator part, has a zero to 45% duty cycle range at either output, pins 11 and 14. Pin 11 is used to drive a single ended output circuit.



The range of adjustment for the 3825 is *approximately* 2.5 to 5 volts at pin 3 for zero to 45% duty cycle adjustment. This approximate voltage range cannot be relied upon for output control without correction.

The error amplifier within U101, the element marked ER, is disabled by connecting it as a voltage follower and amplifier U103B is interposed for a precise comparison of the set point and the feedback.

Setpoint level arrives as the AMPLITUDE signal from the control board. L101 serves to reduces noise. The approximate 0 to 10mA level is converted to a voltage of 0 to -1 volts via the virtual ground of U103A. In the coag modes, K103 is energized shunting a portion of the input current to ground through R155 and R116. This scales the current to a maximum output current of 80 watts. D114 serves as a "coag mode energized" indicator. The setpoint level is rationalized as -1V = 120 watts output. U103A is connected to the virtual ground of U103B's inverting terminal by potentiometer R114. This converts the output voltage of U103A to a current which will equal that of PWRFBK. R114 is used to set the slope of the signal. Since U103B operates as an integrator, with open loop gain, the setpoint input will drive the output in a positive direction, increasing the duty cycle of the exciter. Feedback (PWRFBK) will reduce the output of U103B, creating an equilibrium.

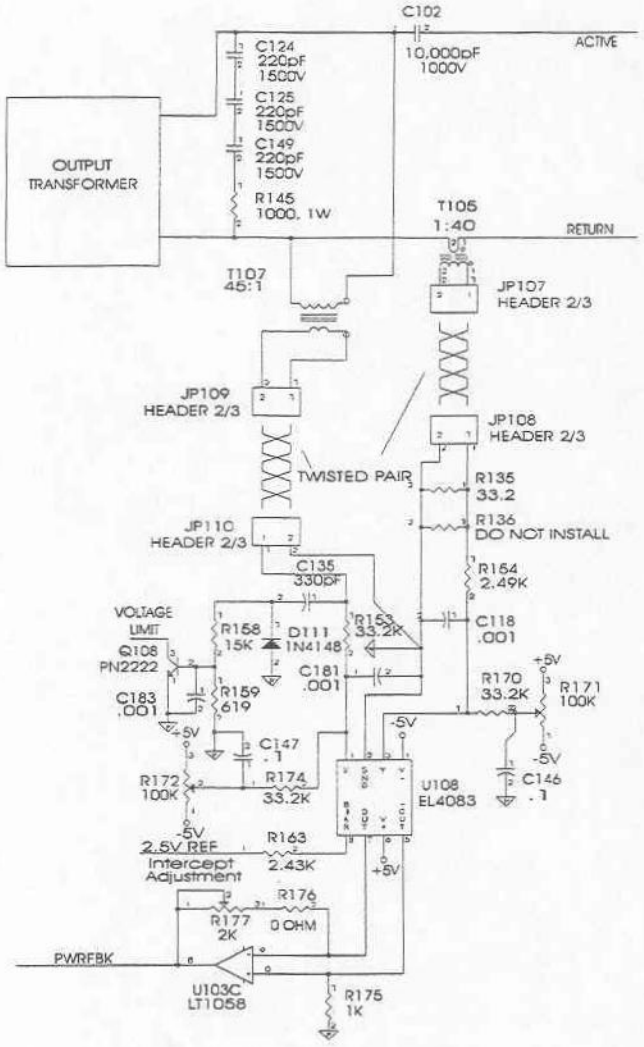
The output of U101 at pin 3 is subject to latch up. To insure maximum duty cycle is reached, the voltage applied as input at pin 2 must exceed the indeterminate maximum input of approximately 5V. Exceeding this input level also causes ER within U101 to latch up, full on. R134 prevents latch up, insuring smooth return to duty cycle control after a maximum output has been reached.

As much as 12V is available as control to pin 2 of U101 by U103B. R104 limits the current into pin 2 of U101. No more than about 6V is seen at pin 2 of U101, the rest being dropped across R148.

Because of available signal polarities, U103B is configured as an inverting integrator. Charges accumulate in C107 and C148 acting as the dominant feedback pole. Values for these components have been selected to prevent oscillation while maintaining fast control of the output.

2.4 Power Feedback

The LM90 incorporates feedback for load power regulation. When a power value is selected on the front panel, the output voltage and current is adjusted by feedback action to apply the selected power level to the load.



Output voltage to the load is measured by T107. Current is measured by T105 and its burden resistor, R135. C118 and C181 serve to deglitch the signals. The deglitched voltage and current signals are applied to a multiplier, U108. The voltage channel is limited by the diodes D111 to prevent negative spikes from damaging U108. The product of voltage and current is power and the adjustment R176 scales it so that 1V = 125W. R176 is used to adjust the intercept.

While 1V = 125W is a low scale factor, it is necessary because the instantaneous power of the 80 watt COAG2 function is 640 watts (per pulse). U108 must handle the dynamic range of all the various modes.

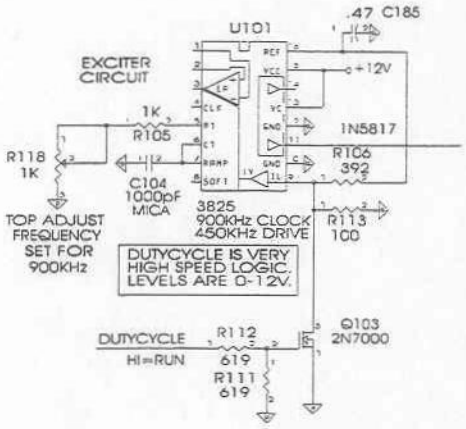
R170 and R172 and associated circuitry are used to adjust any offset errors inherent to the multiplier.

2.5 Exciter Circuit

The exciter provides a 900kHz clock to other functions, drive to the output device and CUT, BLEND, COAG duty cycle modulation. R133 is used to calibrate the frequency.

The various functions are related in this fashion:

CUT	continuous output	
BLEND1	bursts of 50% duty cycle	8 pulses of 16
BLEND2	bursts of 37.5% duty cycle	6 pulses out of 16
COAG1	bursts of 18.75% duty cycle	3 pulses out of 16
COAG2	bursts of 12.5% duty cycle	2 pulse out of 16



To enable these burst modes, the 3825 IC must be controlled at very high speed. The fastest port available for control is the current limit function, pin 9. Pin 9 ordinarily functions to turn off the output at 1V, corresponding to a current limit. Since it is capable of mid-cycle output interruption, it is ideal for burst control.

R106 and R113 establish a shutdown voltage level slightly above the 1V shutdown threshold. Q103 pulls pin 9 below the 1V shutdown potential upon command from the control/display board (DUTYCYCLE). The signal arrives as zero and +12V logic signals. R111 and R112 suitably scale the current from this logic level to a value compatible with the gate of Q103. R111 both refers the incoming signal to local ground for noise immunity and provides a path for the stored charge of Q103's input, speeding turn off.

2.6 Output Circuits

The heart of the LM90 output section is Q105 a power MOSFET. It receives drive from the exciter circuit through R133. D107 prevents negative reflections from Q105's gate from driving the output of the exciter below ground. D118 limits the positive relections to approximately 12V.

The drive to Q105 is a pulse of constant amplitude, approximately 12V, at a constant repetition rate, 450kHz, of zero to 1 micro second width. The width or duty cycle modulation adjusts output power levels. The duty cycle modulation is responsive to power measured to the load by the circuits associated with T105 and T107.

In the source of Q105 a current transformer T106 measures the switching current of Q105 for limiting action. Current limiting is principally to prevent nuisance fuse clearings. Line fuse selection is set by input transformer temperature rise according to UL2601.

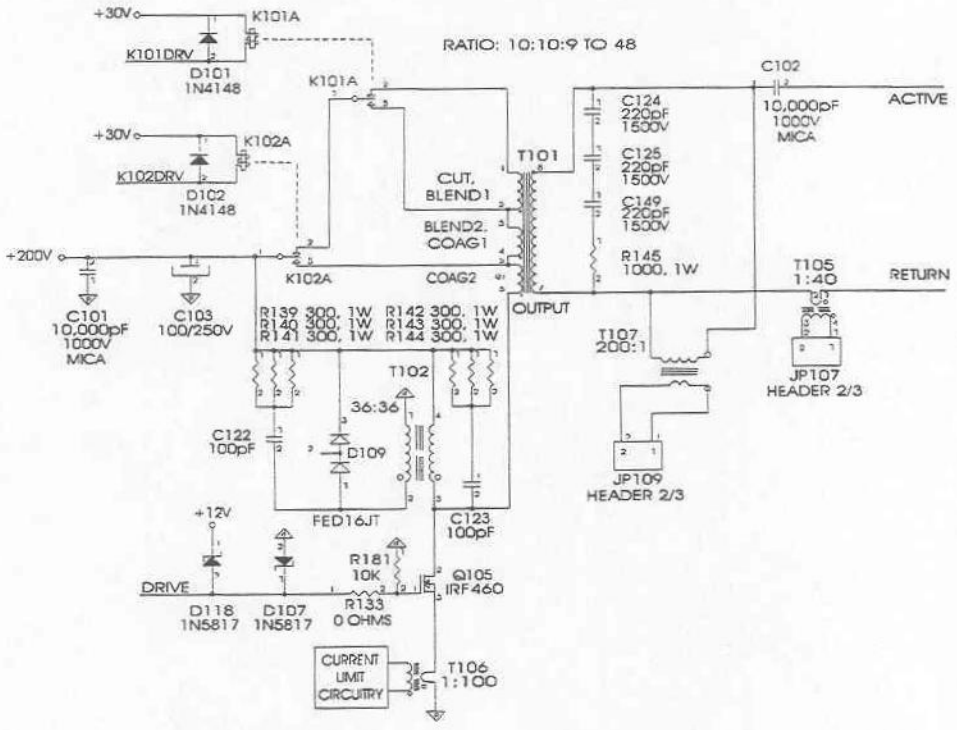
The drain of Q105 switches the 200V supply rail through T101 and T102 simultaneously. T101 transforms and isolates the output. T102 allows 4 quadrant operation of the output at very high efficiency.

The primary of T102 allows the drain of Q105 to hard switch to zero volts, applying 200V across the primary windings. Energy stored or reflected from the output appears in both the primary and secondary of T105. In the secondary stored or reflected energy can rise no higher than the 200V supply rail before it forward biases D109, returning the energy to the supply and conserving it.

This action places bounds of zero and 400V on the potential seen at the drain of Q105. No combination of supply and load characteristics can exceed these limits, promoting high reliability. In addition, three snubber networks comprising C122, C123, and series C124, C125, C129 and their associated resistors clean-up the switching waveforms, eliminating the effects of leakage inductances and distributed capacitances. The total energy budget for all three snubber networks is 5 watts at maximum output.

Different modes of operation demand different output voltages. For example, COAG2 at 80 watts into 300 ohms, 2/16th duty cycle, requires 438V instantaneous rms, something approaching 1,239V peak to peak, depending upon waveshape. If T101 is wound to produce that output with 400V peak to peak input, the result is a very disadvantageous turns ratio for CUT operation which requires 190V rms into 300 ohms for 120 watts of output. Efficiency, reliability and quality of control suffer with a fixed ratio.

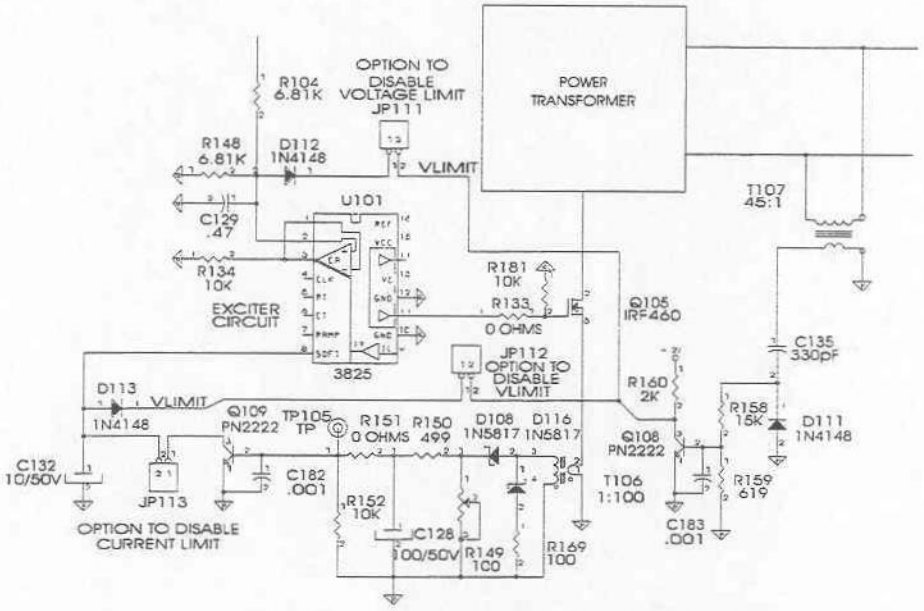
Accordingly, T101 has three primary taps to select a "best" supply to load match for the CUT, BLEND and COAG modes. The relays K101 and K102 are responsive to user mode selection.



2.7 Limits Circuitry

The limits circuitry imposes bounds on the LM90 voltage and current outputs. The current limit prevents excessive current flow, for example into a shorted output, from causing a nuisance fuse clearing. It also lowers stresses on the switching element, Q105, and the power supplies.

The voltage limit circuitry places limits on permissible maximum output voltages. These limits are not hard or exact. The output may be seen to oscillate when in a limit. Oscillation in a limit is permissible.



Current is limited at the source electrode of the switching element and voltage is limited across the output transformer.

Both current and voltage limits are *averaging functions*. Current averaging is done by the networks D108, C128, R150, R152, D116, R169 and Q109. R149 may be adjusted for the desired current limit. Voltage limiting comprises R158, R159, C182 R160 and Q108. There is no adjustment for the voltage limit, however, it is set for approximately 300Vrms maximum, into an open circuit. As the various CUT, BLEND and COAG modes are employed, the maximum voltage and current characteristics of the output change.

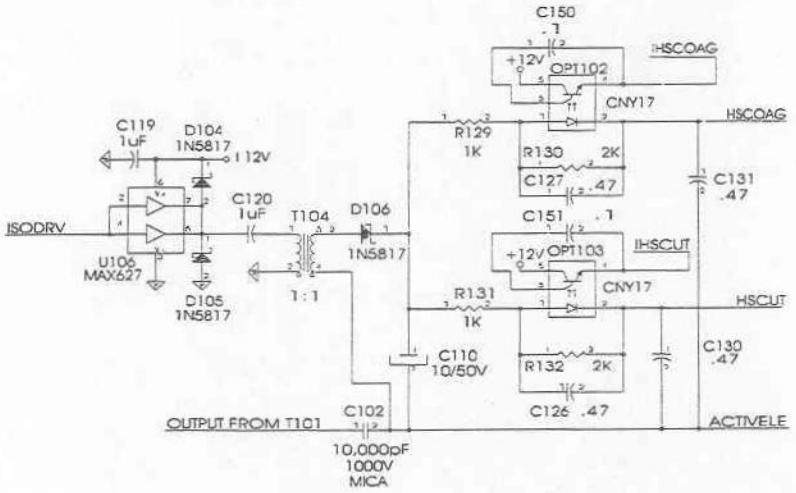
Both limiting functions are designed to reduce the duty cycle of U101 to a non-self destructive level. A redundancy for voltage limits is provided by D112 and D113. Although the redundancy is not a necessity, it affords a cost effective. These functions are diode isolated from normal power feedback control. They come into play only when a value of voltage or current exceeds power feedback levels.

2.8 Handswitch Power and Readback

The handswitch power and readback circuit provides isolated logic signals indicating the status of the CUT and COAG buttons on the electrosurgery tool.

To hold wiring to a minimum, the CUT and COAG switches are common to the ACTIVE electrode and may ride an RF potential of 3000V peak to peak. Both voltage isolation and capacitive isolation are required for proper circuit operation. Optoisolators and special transformers are used for isolation.

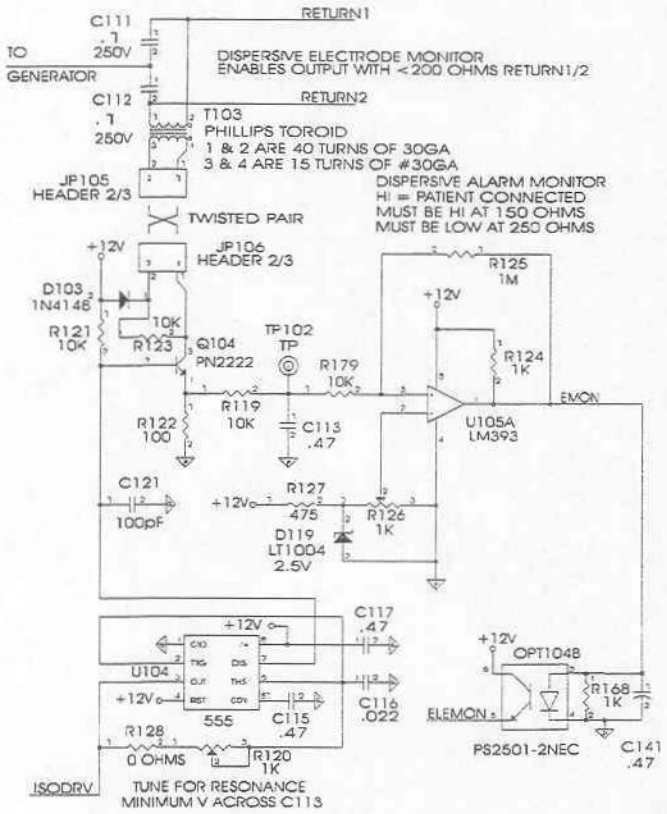
A 50kHz clock signal from the Dispersive Alarm Monitor circuit is applied to a MOSFET driver IC, U106, to generate a low impedance 50kHz, 12V squarewave. This is isolated by transformer T104, rectified and filtered into DC. T104 is a triple-split bobbin transformer with primary and secondary windings on only the ends of the bobbin for additional voltage withstand and low leakage capacitance.



CUT or COAG handswitch closures cause current to flow through the associated optoisolator. Current through the LED is limited by R129 and R131 while R130 and R132 serve to insure the LED will not be "tickled" into light emission by RF leakage currents.

The photo transistor side of the optoisolators pulls up to 12V creating a high noise immune signal for the control/display board. C150 and C151 prevent noise from turning on the isolators.

2.9 Dispersive Alarm Monitor



The dispersive alarm monitor tests the patient return electrode leads for less than 200 ohms resistance between the split halves. It performs this function by monitoring the current fed to a resonant circuit.

The resonant tank comprising the secondary of T103 along with C111 and C112 is tuned to approximately 50kHz. The effective value of the C111, C112 combination is .050 uF which is split to provide a common mode connection for the return electrode transformer connection.

The RF voltage across the patient return electrodes is basically in phase and equal, promoting additional cancellation of interfering signals.

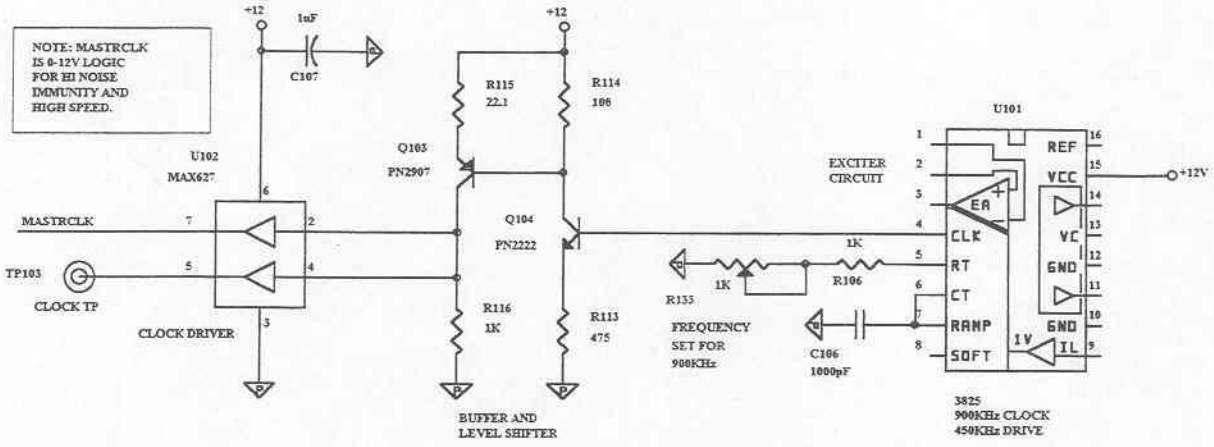
The same network of C111, C112 applies the 50kHz sense signal differentially to the split patient electrode. A load imposed by the patient will be reflected through T103 and monitored as an increase in average voltage across R122. R119, C113 is the averaging network and adjustment R126 sets the 200 ohm threshold into comparator U105A.

The transformer T103 has a triple split bobbin with the center winding area empty for extra voltage isolation. Because the value of T103's inductance cannot be closely controlled, an adjustment, R120, is necessary to resonate T103, C111, C112 at approximately 50kHz. At resonance, the voltage across R122 will reach a minimum value, indicating minimum current flow. The output is sent to the control/display board by OPT104B which isolates and eliminates ground shifts between the two boards.

2.10 Master Clock

A generic 3825 switchmode power supply control IC provides the master clock for all LM90 operations except some elements of the DC power supply which are self clocking. Control of such functions as blend and coag mode duty cycle requires low clock skew synchronization of the output and controlling circuits.

The components R106, R133 and C106 adjust the frequency of the 3825 to a stable 900kHz value. The signal is available at TP103 for a frequency counter measurement. An internal divide by two within U101 causes the output of the generator to have a 450kHz fundamental output.



The clock output of the 3825, pin 4, is produced at an awkward level of *approximately* 2.5 to 4.5 volts. It is designed to synchronize other 3825 ICs. The circuit comprising Q103, Q104 and the associated resistors amplifies and level shifts the pin 4 output to zero and +5V levels suitable for the input of U102, a MOSFET driver used here as a clock buffer.

The output of U102 is a fast, hard switched, zero and +12V level at a low impedance. This is important because it must clock the control/display board remotely in a very noisy RF environment. At the control board, zero and +5V logic levels are recovered locally against the board ground by a resistor divider network. The speed of U102 and the low impedance of the resistor network insure very low clock skew between the two boards.

3. Controller Board Theory of Operation

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3.1 Introduction

This document describes the theory of operation for the Controller Board, for the LM90 ESU power supply. It is a technical document and it's intended audience are all manufacturing/test engineering personnel.

3.2 Block Diagram

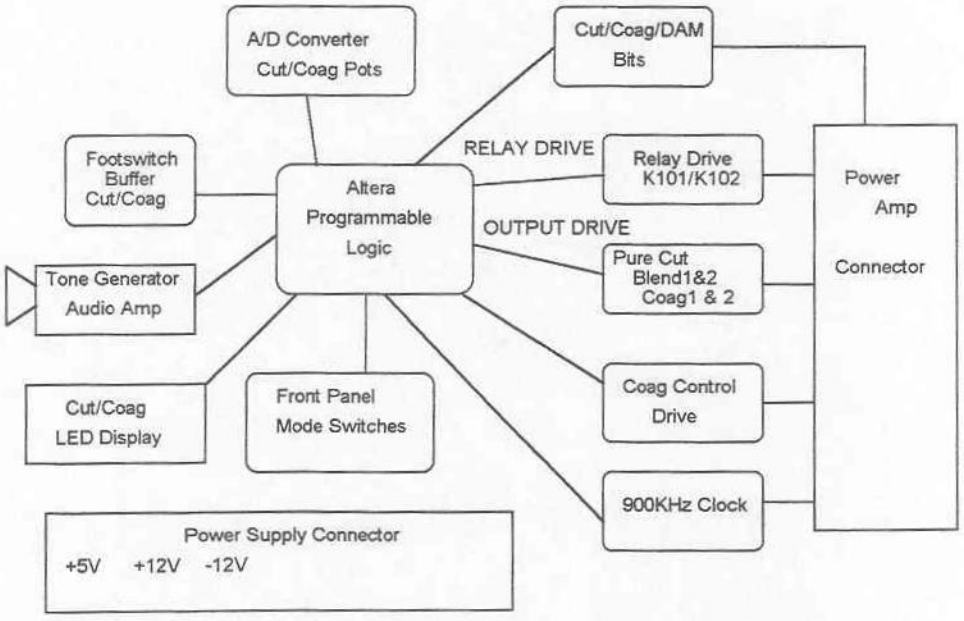


Figure 1 Block Diagram of Controller Board

3.3 System Definition

Figure 1 show a Block Diagram of Controller Board. The major sections of the controller board are the LED display system, the A/D converter system, the audio system, the switch/DAM input section, the LED status section and the output drive section.

3.4 LED Display System

There are two groups of 7 segment LED displays mounted on the component side of the controller board. One group displays the Coag wattage set point and the other group displays the Cut wattage set point. Digit display and multiplexing is accomplished by U201, an Altera gate array.

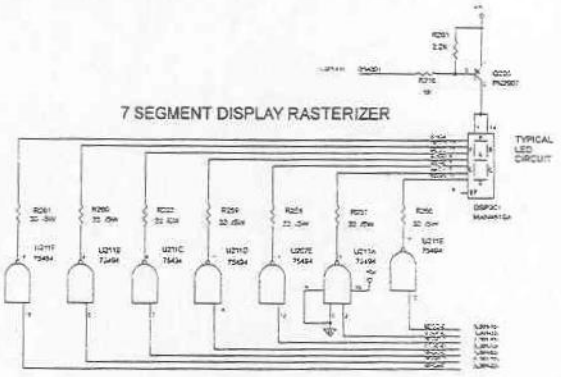


Figure 2 LED Drive Circuit

The operating current for each segment has been set to approximately 100mA with a 25% duty cycle per digit (the 100's Cut digit is done in parallel with the Cut 1's digit). U207 and U211 sink current for each segment of a digit. Current limiting for each segment is done by R256, R257, R258, R259, R223, R260, R261.

DSP201 and DSP202 and their associated drive transistors, Q205 and Q206, provide 10's and 1's wattage set point indication for Coag mode. The set point can be adjusted from Zero to 80 Watts.

DSP205, DSP203, and DSP204, with their associated drive transistors Q207, Q208, Q209 provide 100's, 10's and 1's wattage set point indication for the Cut mode. The set point can be adjust from Zero to 120 Watts. DSP205 is different from the other displays, in that, it displays only the digit '1'.

3.5 A/D Converter

The purpose of the A/D converter system is to read the front panel potentiometers and provide a numeric representation for the Cut and Coag power level set point using the LED 7 segment displays discussed earlier. Additionally, the potentiometers are buffered and their output levels are provided to the power amplifier board through connector J202.

3.5.1 Output Reference

U209A and its associated circuitry provides a constant 5.0V voltage reference for use by the A/D system. The reference is used by both the integrator circuit (U202D) and by the panel mount potentiometers. The reference allows the A/D a high degree of noise immunity and power supply rejection.

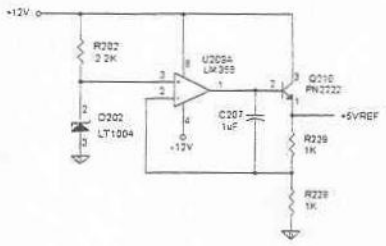


Figure 3 Reference generator

3.5.2 Power Level Potentiometers

As mentioned before, both the Cut and Coag potentiometers use a stable +5V reference for the high side of the pot. To protect the analog signal processing D203, D204, D205, D206 are Schottky diodes which clamp the potentiometer's wiper. Additional protection is provided by R231 and R230, 10KΩ resistors which limit the impedance into multiplexer U203A and operational amplifier U202B and U202C.

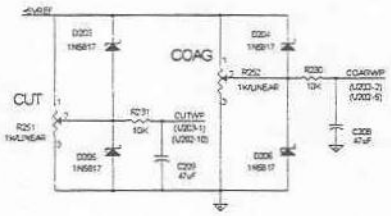


Figure 4 Power Set Point Pots

3.5.3 Output Level to Power Amp Board

U203A (CD4053) 2 channel multiplexer is used to select which potentiometer is used by the power amplifier card. The multiplexer is switched by signal POWERSEL which is generated by U201. U202A, Q211, Q204 and their associated components provide a low impedance, low noise, current mode output to the amplifier card. A 0-5V adjustment on the power level potentiometers will cause a 0-10mA output from the current source.

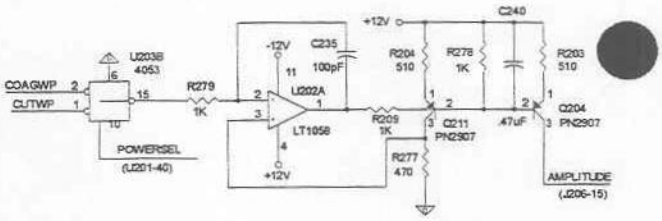


Figure 5 Output Level Drive

3.5.4 A/D Calibration/Upper End Setpoint

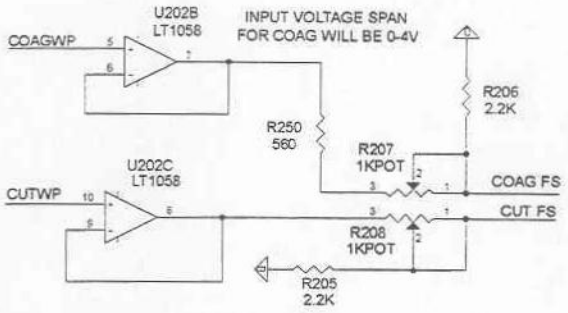


Figure 6 A/D Calibration Circuit

Calibration of the A/D is accomplished through 1KΩ potentiometers, R207 and R208. This allows for full scale (80 for Coag and 120 for Cut) adjustment through trimming of the appropriate potentiometer. Once the set point has been factory calibrated, no further adjustment is needed.

Both CUT and COAG potentiometers has a 0-5V span. To accomplish the 0-80 set point for COAG a voltage divider has been added to the COAG circuitry. R250 provides a 2/3's divider for the COAG input voltage. Thus a 5V adjustment on the COAG potentiometer will cause only 2/3 * 5V or 3.33V input to the A/D converter. Two-thirds of 120 (CUT max. set point) is 80, which is the maximum wattage available for the COAG modes.

3.5.5 A/D Mux Circuit

Multiplexer U203B, selects which channel the A/D converter measures. The multiplexer is switched by signal ADCMUX which is generated by U201. The output of the mux is inverted by U204A to produce a 0 to -5V set point level. This is done because the A/D ramp generator will produce a negative going ramp.

3.5.6 A/D Ramp/Comparator Circuit

U202D and its associated circuitry provides a negative ramp which is then applied to one side of comparator U210A. U202D output will slew negative until the multiplier's value (reading of Cut or Coag potentiometer) is larger than the ramp voltage. This will pull the comparator's output high and cause an end of conversion. ADCCMP end of conversion signal is then fed back into U201 where the A/D data is saved and the next conversion cycle is begun.

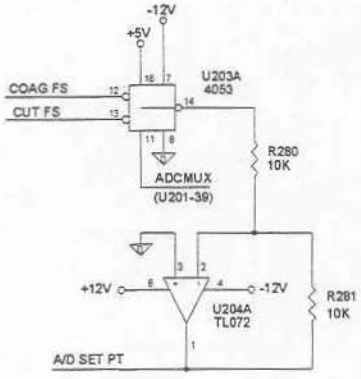


Figure 8 A/D Mux

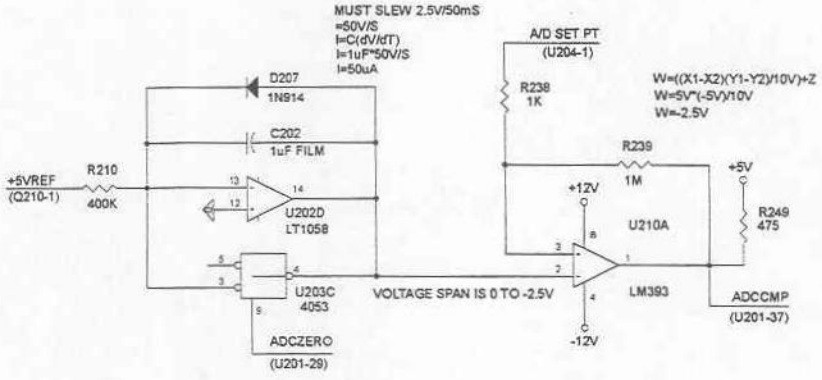


Figure 7 A/D Ramp

3.6 Sound Generation

Tones for the LM90 ESU are generated through a DTMF chip U206 and the audio amplifier chip U205. The DTMF chip uses a standard 3.58 MHz color burst crystal to generate its clock. There are three different tones used by the ESU generator. Each tone is activated by a control signal from U201. The volume is controlled through potentiometer R212 which is located on the rear panel of the LM90.

The alarm tone has the highest frequency output and is modulated on and off at 2 Hz. The alarm tone is generated whenever the patient monitoring circuit detects an error or more than one button is pressed by the hand or foot switch. To comply with AAMI HF-18 the ALARMTONE signal disables the volume adjust control on the rear panel by energizing relay K201. This sets the output level of the audio amplifier to a fixed volume.

The Cut and Coag tones have continuous frequency outputs with the Cut having the higher frequency. Both tones are energized when their associated foot or hand switch is pressed.

The audio amplifier, U205, has a 5 Watt output capability. U205 uses the +12V supply for operation. The supply is highly bypassed using C203, a 470uF capacitor. C205, C224 and R211 provide a low pass filter and

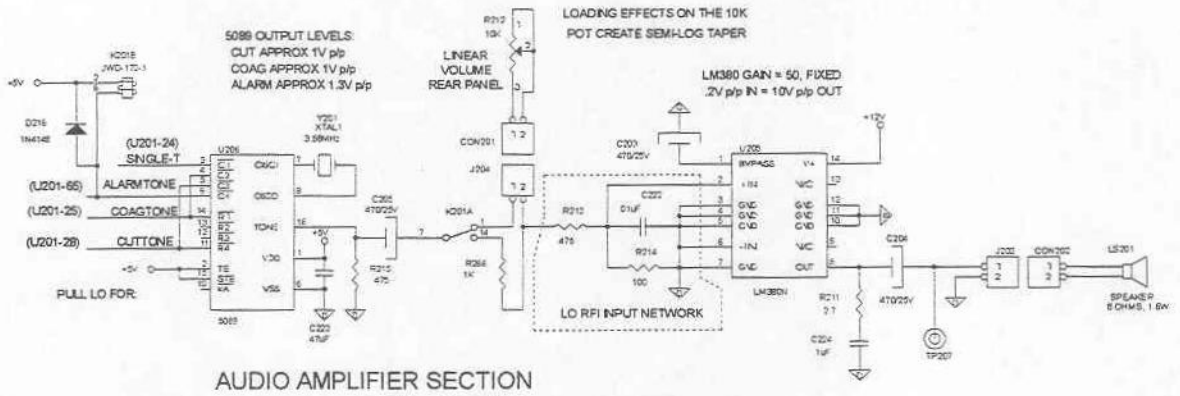


Figure 9 Audio Amplifier Section

DC decoupling for the speaker.

3.7 Switch/DAM Inputs

3.7.1 Coag Mode Switch

The Coag Mode switch is a two position circuit board mounted rotary switch. Modes Coag1 and Coag2 are selected using this switch. Whichever mode is currently selected when the foot or hand switch is depressed will cause that mode of operation by the ESU generator.

Each of the inputs is pulled to +5V. When a given switch is selected its position will be grounded. The input signals to U201

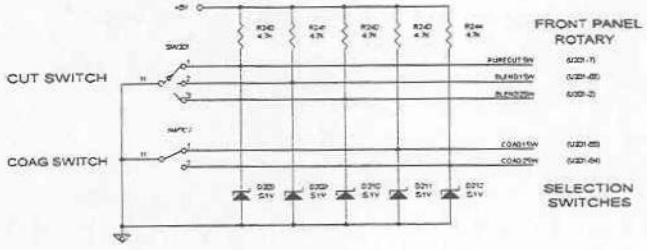


Figure 10 Switch Inputs Conditioning

are protected from static electricity through D211 and D212, 5.1V zener diodes. The input signals are NTL, negative true logic.

3.7.2 Cut Mode Switch

The cut mode switch is a three position circuit board mounted rotary switch. Modes Pure Cut, Blend1 and Blend2 are selected using this switch. Whichever mode is currently selected when the foot or hand switch is depressed will cause that mode of operation from the ESU generator.

Each of the inputs is pulled to +5V. When a given switch is selected its position will be grounded. The input signals to U201 are protected from static electricity through D208, D209, D210, 5.1V zener diodes. The input signals are NTL.

3.7.3 Footswitches

Opto-isolator OPT201A and OPT201B are used to buffer the foot switch signal. Normally the input diode's cathode rests at near +5V. Closing the appropriate foot switch will cause the cathode to be pulled to ground turning on the opto's LED. The insure good noise immunity R233, R232 and C227, C228 provide filtering and sets the minimum current required to turn on the LED. Assuming a 2V drop across the photodiode for turn on it will take 1mA of current to turn on the opto's photodiode. R236 and R237 are used to current limit the current through the photodiodes. The output signal from the opto-isolator's are fed to U201 and are NTL.

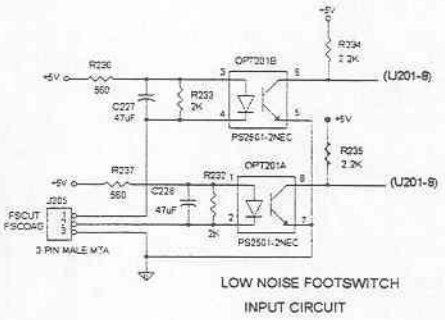


Figure 11 Footswitch Conditioning

3.7.4 DAM Status

OPT202C is used to buffer the DAM status bit from the amplifier. Signal ELEMON from the amplifier board must be pulled to +12VDC for the opto to turn on. To improve noise immunity C238 has been added. The minimum current for turning on the diode is set by R271.

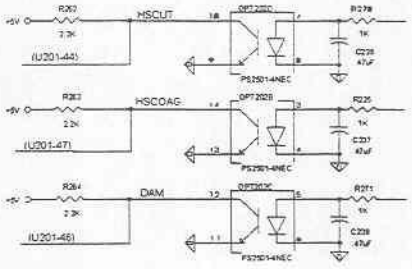


Figure 12 DAM/Handswitch Conditioning

3.7.5 Handswitches

The CUT and COAG handswitches status bits are generated on the amplifier board. Signals are returned to the controller board as currents. These bits are buffered identically to the DAM status bits above using OPT202D and OPT202B.

3.8 Status LEDs

There are four status LEDs associated with the controller card. They are located on the component side of the circuit board and are mounted with spacers to reach through the front panel. Three of the LEDs, ERROR, CUT and COAG are controlled by U201. The fourth LED is the power on status LED and will remain on while power is applied to the controller card.

The color of the LEDs are as follows:

LED	*COLOR*
POWER	GREEN
ERROR	RED
CUT	AMBER
COAG	BLUE

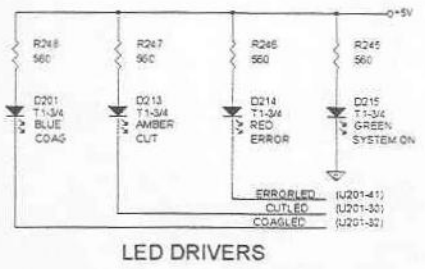


Figure 13 Status LED Drive Circuit

3.9 Output Drive

There are five different output drives for the power amplifier card. Each drive relates to one of the 5 modes of operation, Pure Cut, Blend1, Blend2, Coag1 and Coag 2. The waveform generated by the controller card is not the output waveform from the amplifier card. Instead, the output from the controller card is logically AND'ed with the amplifier's 900 kHz clock to produce the output waveform. This allows 0-16 pulses to be generated at the amplifier's output depending on the controller card drive signal.

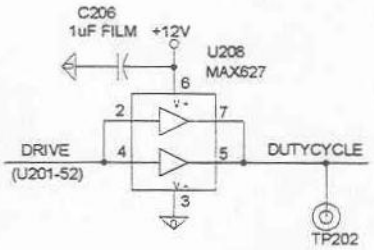


Figure 14 Output Driver

3.9.1 Pure Cut Mode

This mode of operation provides a continuous output to the power amplifier board. There are 16 pulses generated in this mode. Since the process is repeated after 16 pulses this mode of operation provides continuous pulses at the amplifiers output.

3.9.2 Blend 1 Mode

This mode of operation provides a 50% duty cycle drive signal. There are 8 pulses in this mode.

3.9.3 Blend2 Mode

This mode of operation provides 37.5% duty cycle drive signal. There are 6 pulses in this mode.

3.9.4 Coag1 Mode

This mode of operation provides 18.75 duty cycle drive signal. There are 3 pulses in this mode.

3.9.5 Coag 2 Mode

This mode of operation provides 12.5% duty cycle drive signal. There are 2 pulses in this mode.

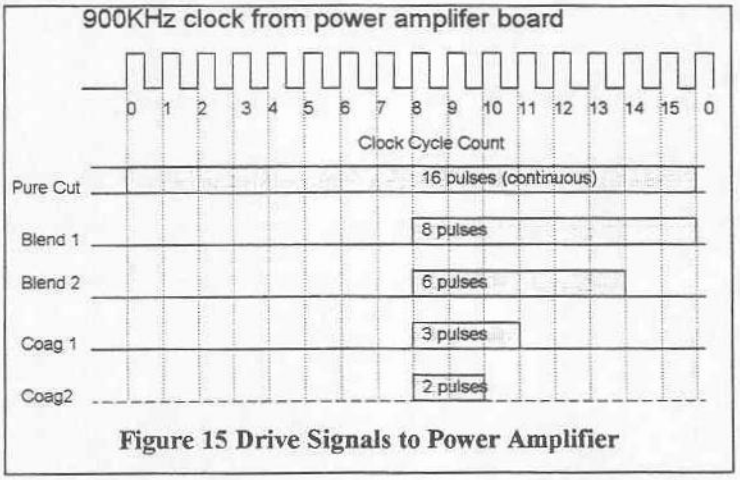


Figure 15 Drive Signals to Power Amplifier

4. Power Supply Board Theory of Operation

4.1 Introduction

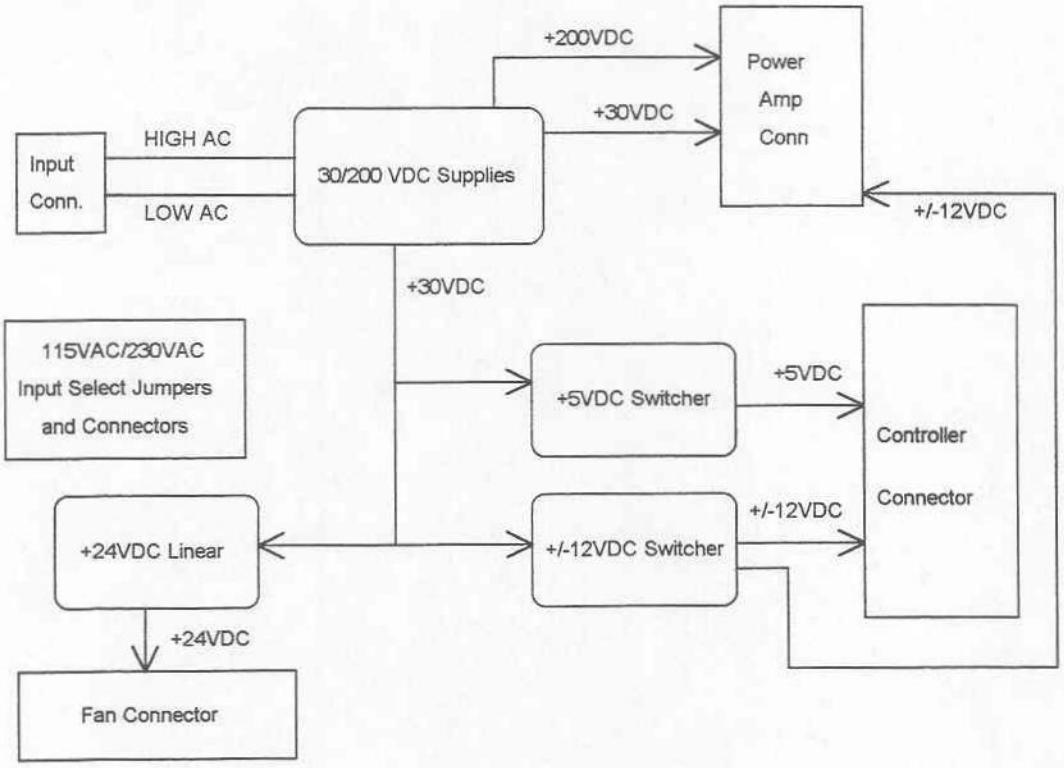
This document describes the theory of operation for the Power Supply Board, for the LM90 ESU generator. It is a technical document and it's intended audience are all manufacturing/test engineering personnel.

4.2 Specifications

The following table describes the output specifications for each of the power supplies provided on this board.

	+200 V	+30 V	+24 V	+12 V	+5 V	-12 V
Vout MINIMUM	165 V	25 V	23 V	11.9 V	4.8 V	-11.5 V
Vout MAXIMUM	225 V	35 V	25 V	12.4 V	5.2 V	-12.8 V
Iout MAXIMUM	2 A	2.25 A	.2 A	.5 A	1.25 A	-.3 A

4.3 Block Diagram

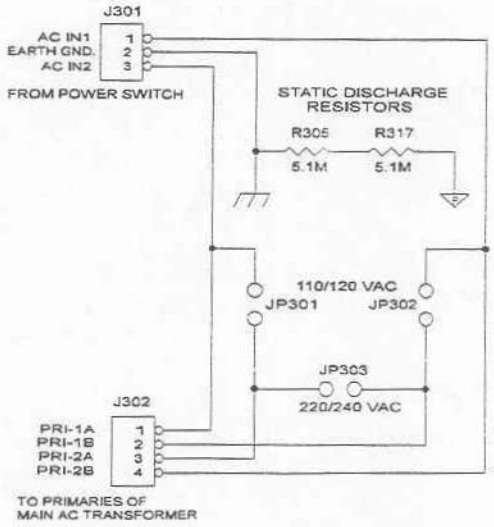


4.4 110VAC/220VAC Mode Selection

The LM90 is designed to operate at either 110/120VAC or 220/240VAC. Connector J301 provides AC from the power switch. A strapping option on the power supply board (JP301 and JP302, or, JP303) allows the two primary windings to be connected in parallel (120VAC mode) or connect in series (240VAC mode). Connector J302 provides AC output to the primary side of the Main AC transformer.

Resistors, R305 and R317, provide a high impedance connection between the AC ground and the power supply ground. This connection is know as the "Drain" connection and prevents static electricity from building up between the two grounds.

4.4.1 Schematic diagram: AC Input Selector



4.5 AC Rectifier/Filter

The Main AC Transformer has two secondaries, a low AC side (yellow wires) which is nominally 22 VACrms, and a high AC side (red wires) which is nominally 143 VACrms. Both secondaries are brought onto the Power Supply board via connector J303.

4.5.1 +30 Volt DC Supply

The LOW AC secondary winding enters the board through J303-1 and 2 (pin 1 and pin 2). The AC voltage is immediately rectified through BR302, a 400V PIV 10 Amp bridge rectifier. C302, C303 and C304 are low ESR electrolytic capacitors which provide initial DC filtering for the unregulated supply which is nominally 30VDC. This unregulated source will vary in relation to the AC LINE voltage produced by the Main AC Transformer.

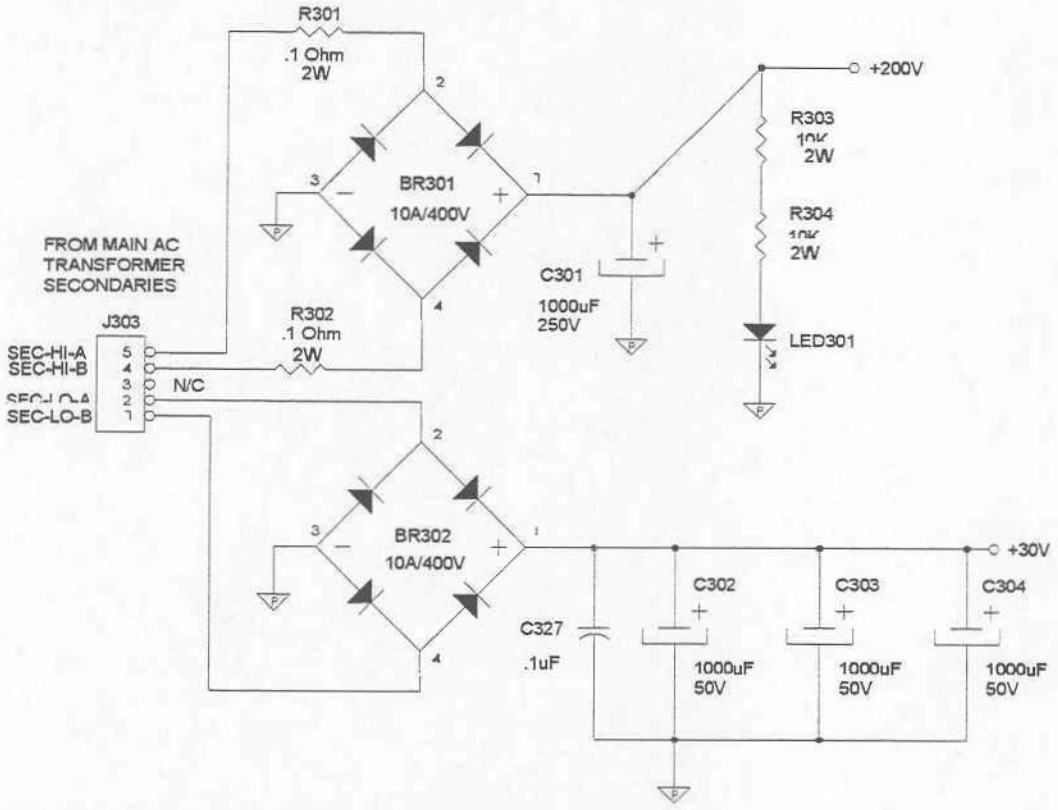
This supply is the source for all of the regulated supplies on this board and also supplies the Power Amp Board via J305-6, and may be monitored at TP306, labeled **+30V**.

4.5.2 +200 Volt DC Supply

The HIGH AC secondary winding enters the board through J303-4 and 5. The AC voltage is immediately rectified through BR301, a 400V PIV 10 Amp bridge rectifier. C301 provides bypassing for this unregulated supply which is nominally 200VDC. R303 and R304 and LED301 provide a power status reading for the 200VDC as well as a bleeder resistance for the high voltage supply. This unregulated source will vary in relation to the AC LINE voltage produced by the Main AC Transformer.

This supply delivers power to the Power Amp Board via connector J305-1 and 2, and may be monitored at TP305, labeled **+200V**. **CAUTION! This is a HIGH VOLTAGE supply capable of supplying large DC currents. Use care when testing, or servicing, this circuit!**

4.5.3 Schematic Diagram: +200 Volt and +30 Volt Supplies

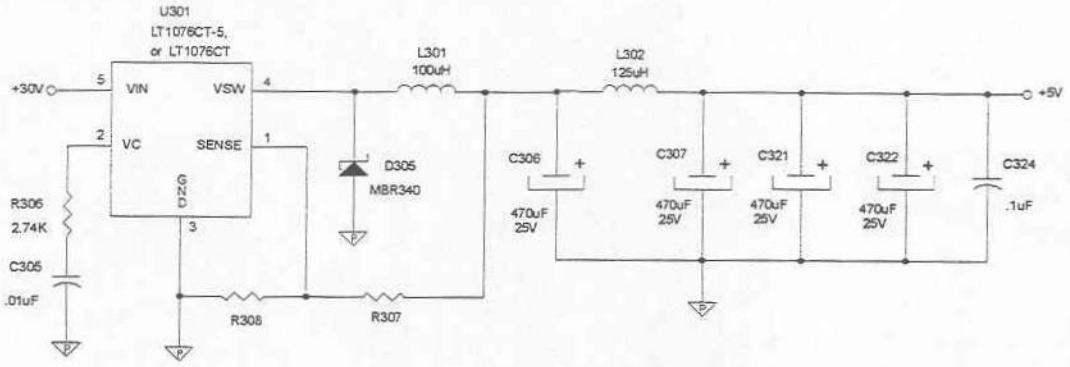


4.6 +5V Buck Mode Power Supply

4.6.1 Circuit Description

The +5VDC supply is designed around the Linear Technology LT1076CT-5 Step-Down Switching Regulator (U301) configured as a classic positive Buck Converter with a pre-set 5Voutput. The LT1076CT incorporates the power switch, all oscillator and control circuitry, all current limit components, and an output monitor on the chip. The oscillator frequency is pre-set to 100 kHz. Current limiting is performed on a pulse-by-pulse basis and is pre-set to 2.6 Amps. In addition to the LT1076CT-5, provisions are made on the circuit board to also accept the LT1076CT, an adjustable output version, with simple resistor changes.

4.6.2 Schematic Diagram: +5 Volt Supply



4.6.3 Circuit Operation

When +30V supply becomes greater than 8VDC presented to U301- 5 (pin 5), the regulator will commence operation. During operation, U301-4 provides a gated, 100 kHz pulse stream via toroidal inductor L301 (and Schottky diode D305 during flyback) to charge capacitor C306, and maintain a +5VDC output voltage which is reported back to U301-1 via R307 (and R308, if adjustable output is used). Additional filtering and bypassing is provided by inductor L302, low ESR electrolytic capacitors (C307, C321 and C322) and a ceramic capacitor, C324. The RC series network, R306 and C305, provides frequency compensation for U301's internal voltage gain circuitry.

The actual values of R307 and R308 depend on which part option is used for U301: the fixed output part (LT1076CT-5) has an internal resistor divider, and thus, requires R307 to be a short circuit and R308 to be open; the variable output part (LT1076CT) requires R307 to be a 2.80KΩ and R308 to be 2.21KΩ. To calculate the resistor values necessary to produce a given output when using the LT1076CT, use the following formula: Vout = 2.21 (R307+R308) / R308, where 2.21 is the internal reference voltage used for output comparison.

4.6.4 Output Specifications

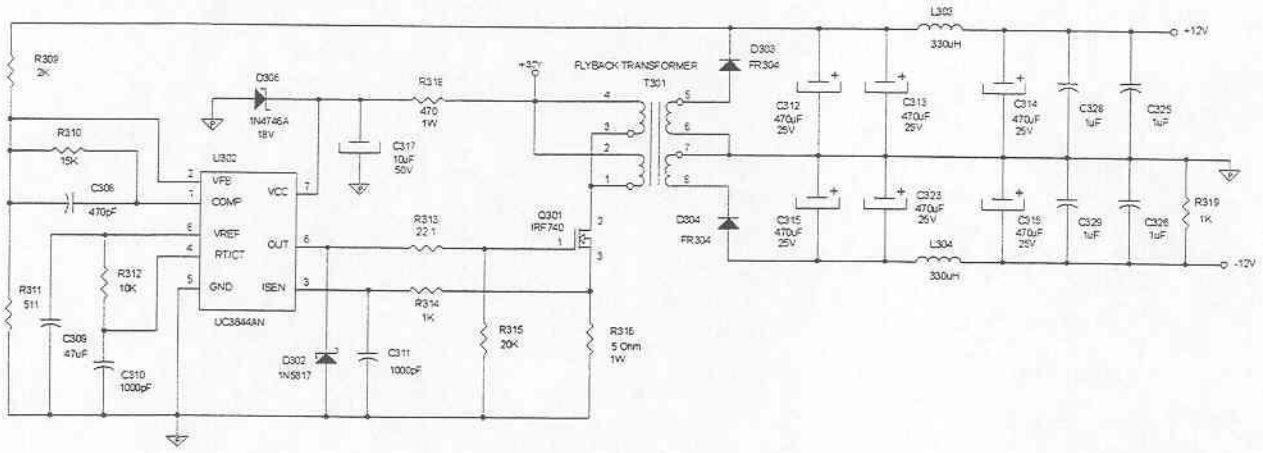
The +5V supply shall deliver from 4.8 to 5.2 VDC at 1.25 Amps continuously. This supply delivers power only to the Controller Board via connector J304-1, and may be monitored at test point TP304, labeled **+5V**.

4.7 +/-12V Switch Mode Power Supply

4.7.1 Circuit Description

The +/-12VDC supply is designed around the Unitrode Integrated Circuits UC3844AN Current Mode PWM Controller (U302) configured as a flyback regulator. The generation of two supplies is accomplished by the use of a dual secondary transformer, although feedback and control are applied only on the +12V side. The -12V supply is therefore parasitically regulated and is subject to fluctuations due to changes, or imbalances, in loading of either itself, or the +12V supply.

4.7.2 Schematic Diagram: +/-12 Volt Supplies



4.7.3 Circuit Operation

The flyback controller, U302, will start operation when the +30V supply reaches approximately 16 Volts. The Vcc input, U302-7, is supplied from the +30V supply via an over voltage protection network consisting of R318, an 18V zener diode D306, and a bypass capacitor C317. This protection is necessary due to the 30V maximum input limit of the UC3844AN.

An internally generated 5 Volt reference is provide at U302-8 to charge the RC oscillator network of R312 and C310. Capacitor C309 provides bypassing for the reference voltage. The oscillator is design to operate at 172 kHz, yielding an output switching frequency of 89 kHz. The relationship of the oscillator frequency to the RC network is given by: Fosc = 1.72 / (R312 x C310).

Flyback operation begins when U302's output (pin 6) energizes the gate of the N-channel power MOSFET, Q301, through R313. This causes Q301 to turn on and stores energy from the +30V supply in the primary of toroidal transformer T301. With the end of the first pulse, R315 pulls Q301-1 toward ground, turning off Q301. The Schottky diode D302 protects U302-6 from going too far below ground during turn-off. T301's primary then flies back, inducing current in the secondaries. Fast recovery rectifiers (D303 and D304) on the secondaries direct the induced voltages to low ESR storage capacitors for each supply, C312 and C313 for +12V, and C315 and C322 for -12V. The operation continues at the switching frequency until the charge accumulated on C312 and C313 reaches the designed output and is reported back to the voltage feedback input of U302, pin 2, via the resistor divider of R309 and R311. An internal error amplifier compares the input to an internal 2.5 Volt reference. The relationship of the resistor divider to the output voltage is: Vout = 2.5 (R309+R311) / R311. The error amplifier's voltage gain is set by the relationship of R309 and R311 to R310. R310 with C308 provide frequency compensation with a roll-off of approximately 1/4 of the switching frequency.

The current limiting circuitry consists of R316, a ground referenced resistor which develops a voltage proportional to the current through Q301, and an RC filter (R314 and C311) to smooth the waveform presented to the current sense input of U302 (pin 3). The voltage is compared to the output from the error amplifier clamped which is clamped to 1 Volt by an internal zener diode. Therefore, the current limit is established at approximately 1 / R316.

The final output filter for the +12V supply is formed by inductor L303 and C314, a low ESR electrolytic capacitor, and ceramic capacitors, C325 and C328. The -12V supply has a similar design (L304, C316, C326 and C329, respectively), except, it has an additional resistor, R319, to ground that provides a means of balancing the supply load with the +12V load.

4.7.4 Output Specifications

The +12V supply shall deliver from 11.9 to 12.4 VDC at .50 Amps continuously. This supply delivers power to the Controller Board via connector J304-3 and the Power Amp Board via connector J305-5, and may be monitored at test point TP302, labeled **+12V**.

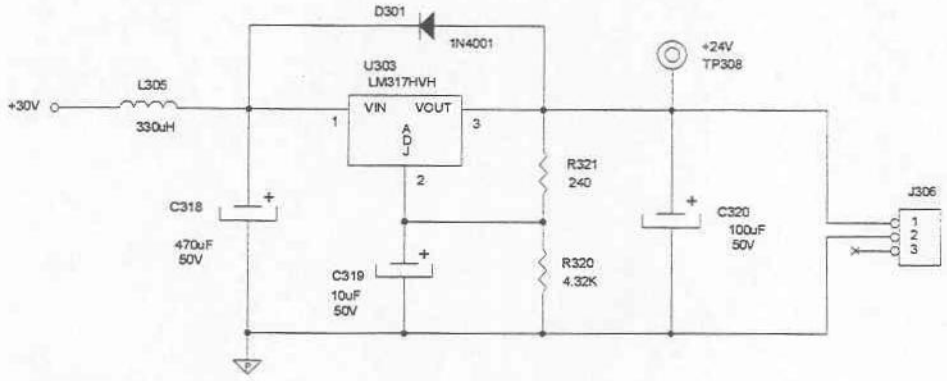
The -12V supply shall deliver from -11.5 to -12.8 VDC at .30 Amps continuously. This supply delivers power to the Controller Board via connector J304-4 and the Power Amp Board via connector J305-7, and may be monitored at test point TP301, labeled **-12V**.

4.8 +24V Linear Power Supply

4.8.1 Circuit Description

The +24V supply is used to power the internal D.C. fan used to cool the LM-90. This supply is designed around the classic LM317 series of adjustable linear regulators, U303.

4.8.2 Schematic Diagram: +24 Volt Supply



4.8.3 Circuit Operation

The +24V supply regulation begins when the +30V supply reaches approximately 26 Volts. U303 is decoupled from the +30V by inductor L305 and capacitor C318. output The LM317 develops a 1.25 Volt reference across R321 causing a constant current to flow through it and down through R320 to set the output voltage. The output voltage is calculated by the formula: Vout = 1.25 (R321 + R320) / R321. C319 is included to provide ripple rejection and helps to reduce overall system noise. Output filtering is performed by capacitor C320. If power is removed from the system while C320 is still charged, D301 protects the output terminal of U303 from damage provides a means to discharge the capacitor.

4.8.4 Output Specifications

The +24V supply shall deliver from 23 to 25 VDC at .20 Amps continuously. This supply delivers power to the Internal Fan via connector J306, pin 1, and may be monitored at test point TP308, labeled **+24V**.

4.9 Circuit Grounds

The Power Supply circuit board has a ground plane "flooded" around most of the component traces on both sides. This ensures a low impedance return path for the power supplies. There are two test points, labeled **GND**, on the board to assist in monitoring the power supplies: TP303, located near J304; and TP307, near J305. The jumper JP304 is installed to provide an additional ground connection for the Power Amp Board via J305-8.

4.10 Calibration

All power supply outputs are provided at values fixed by the components installed on the board. No adjustments are necessary.

4.11 Testing

All supplies, except +30V and +200V DC, are to be tested to 10% and 110% of their stated output specifications using AC inputs that encompass the voltage range expected from the Main AC transformer during normal use. The +30V supply is to be measured for voltage compliance while the other supplies are supplying their loads. The +200V supply is to be tested into an open circuit to verify proper rectification and filtering. The AC input selector (120/240VAC) need not be tested, but continuity must be verified after installation of the mode selection jumper(s).

5. Power Amplifier Test Procedure

5.1 Introduction

This document describes the test and calibration procedure for the Leisegang LM-90 ESU. Its intended audience are all test engineers, biomedical technicians and production personnel. A knowledge of electronic equipment including but not limited to oscilloscopes, meters and calibration techniques are essential for performing this procedure. If an ESU tester is unavailable, use this formula to calculate output power: $P = E^2/R$.

The circuit board must pass all of the specifications prior to being submitted for final assembly. Any parameters that fail this procedure must be clearly marked and attached to the board. The circuit board must than be submitted for rework .

5.2 Items Required for Testing

The following table lists the equipment needed to perform the LM-90 calibration.

• HP3400 True RMS Voltmeter and standard 300 ohm dummy load. *Note: This equipment can be replaced with a standard ESU tester if available.*	• POT adjustment tool
• Clip Leads approximately 12" in length. Various types, banana jack and minigrabber style.	• Function generator capable of generating at least 500 kHz sine wave at 15Vp-p
• 150-300 ohm calibration load for adjusting the DAM circuit	• Frequency counter capable of measuring a 1 MHz TTL square wave.
• Oscilloscope	• Calibration log part # 720-301701

5.3 Setup

- Insure that power is off.
- Record serial number on worksheet.
- Install the power amplifier circuit board in the test fixture.
- Connect cable assemblies to: JP101, JP102, and JP103.
- Install cables to the dispersive and active electrodes.

5.4 Oscillator Adjustment

Its is imperative to adjust the oscillator frequency prior to delivering power to a calibration load. This is because the output stage of the amplifier is tuned to a specific frequency. A poorly adjusted oscillator frequency will cause low power delivery and heating and possible damage to the output stage.

- Connect a frequency counter to TP101 at the output of U102 pins 5 and 7.
- Apply power to test fixture.
- Adjust R118 for 900 kHz +/- 20 kHz.
- Check off oscillator adjustment on worksheet.

5.5 DAM Oscillator

The oscillator circuit uses a 555 timer for its frequency source. Its output plays into T103's primary and produces a tuned circuit with C111 and C112. A null will be produced at TP102 when the two return electrodes are shorted together.

Oscillator Adjustment

- Install a banana jumper between the two return electrodes. This will short transformer T103 secondary.
- Place an oscilloscope at TP102. This is used to measure the output NULL in the following step.
- Adjust R120 for maximum null. The frequency is unimportant but should be near 50 kHz (+/- 20kHz). If the frequency is 2 or 3 times that amount the null is probably adjusted for the 2nd or 3rd harmonic of the resonant circuit. The circuit will not function properly if not adjusted to the fundamental frequency.
- Remove the short between the two return electrodes.
- Check off DAM circuit frequency adjustment on worksheet.

5.5.1 DAM Comparator

A current is developed through R122 based on the resistance between the two return electrodes. This produces a voltage at TP102. The set point can then be adjusted by R126.

DAM Setpoint Adjustment

- Install the 200 ohm calibration load to the two return electrodes.
- Attach an oscilloscope to the output of comparator U105A-1. This will be used to measure whether the DAM is active or not.
- Adjust R126 so that U105A-1 is high at 200 ohms and below.
- Check off DAM set point adjustment on worksheet.

5.6 Voltage Adjustment

- Ground the current channel by shorting JP110's pins together.
- Adjust the function generator for 450 kHz 10Vp-p square wave.
- Apply function generator to JP108 insuring the ground of the function generator goes to pin 2 of JP108 and that the output of the function generator goes to pin 1 of JP108.
- Place an oscilloscope on TP104. This test point only takes the special Tektronix "small" probe. A very high precision measurement can be done using this test point.
- Adjust R172 for minimum output at TP104.
- Remove function generator from circuit. Remove shorting connector from circuit.
- Check of voltage adjustment on worksheet.

5.7 Current Adjustment

- Ground the voltage channel by shorting JP108's pins together.
- Adjust the function generator for 450 kHz 10Vp-p square wave.
- Apply function generator to JP110 insuring the ground lead goes to pin 2 and the output of the function generator goes to pin 1 of JP110.
- Place an oscilloscope on TP104.

- Adjust R170 for minimum output at TP104.
- Remove function generator from circuit.
- Remove shorting connector from circuit.
- Check off current adjustment on worksheet.

5.8 Output Adjustment

To calibrate the system there is only one set of adjustments used by all five modes of operation. This can be done because we are controlling power not currents or voltages. All 5 modes deliver power to a given load. They just do so by applying more or fewer pulses. The fewer the pulses the more the current. The only adjustment necessary then are to adjust the slope and intercept of the control voltage. This allows exact calibration of the output. Additionally, because COAG modes only deliver 2/3's the power of the CUT modes, a COAG set point adjustment is needed to calibrate their operating point.

5.8.1 Power Setpoint (slope adjustment)

- Install 300 ohm 200 watt non-inductive load to output of the ESU. Alternatively, install the ESU tester to the LM-90's output and insure the load is set for 300 ohms.
- Adjust CUT Select switch for PURE CUT.
- Adjust CUT set point control to full clockwise position. The display should read 120 watts.
- Apply power to the load briefly in PURE CUT mode. Measure the output power.
- Adjust R114 until the ESU produces 120 watts in PURE CUT mode.
- Check off slope adjustment on worksheet.

5.8.2 Zero Setpoint (Intercept adjustment)

- Adjust the CUT set point control for a reading of 10 watts.
- Set the CUT select switch for PURE CUT.
- The 300 ohm test load should remain connected at this time.
- Apply power to the load briefly in PURE CUT mode. Measure the output power.
- Adjust R177 until the ESU produces 10 watts in PURE CUT mode.
- Adjust the CUT set point control for a reading of 120.
- Recheck the 120 watt output in PURE CUT mode. Some minor adjust may be required to trim the output.
- Recheck the 10 watt set point and adjust R177 as required.
- Check off zero adjustment on worksheet.

5.8.3 Coag Adjustment

K103 and R116 and R155 form a current divider which shunts current away from summing junction U103-6 and its virtual ground. The values of R116 and R155 have been selected to shunt approximately 1/3 the current away from the summing junction. Therefore, only 2/3 the output control voltage is available at the summing function. The adjustment of R155 then calibrates the COAG output power to the display set point reading on the front panel.

- Set the COAG select switch to COAG 1.
- Adjust the COAG set point for a reading of 80 watts.
- Assure 300 ohm test load is connected to output.

- Apply power to the load briefly in COAG 1 mode. Measure the output power.
- Adjust R155 until the ESU produces 80 watts in COAG 1 mode.
- Check off coag adjustment on worksheet

5.9 Current Limit Adjustment

- Assure 300 ohm test load is connected to output.
- Set the CUT switch to the BLEND 2 setting.
- Set the output for 120 watts.
- Adjust R149 until output wattage begins to drop.
- Adjust pot back for 120 watt output and continue to turn for 1/8 turn.
- Check off current limit adjustment on worksheet.

5.10 Calibration Complete

This completes the calibration of the LM-90 ESU. Sign and date the worksheet. If the instrument failed any of these tests, it must be clearly labeled and returned for rework.

6. CALIBRATION PROCEDURE

6.1 Introduction

This document describes the test and calibration procedure for the Leisegang LM-90 ESU. Its intended audience are all test engineers, biomedical technicians and production personnel. A knowledge of electronic equipment including but not limited to oscilloscopes, meters and calibration techniques are essential for performing this procedure. If an ESU tester is unavailable, use this formula to calculate output power: $P = E^2/R$.

6.2 Items Required for Testing

The following table lists the equipment needed to perform the LM-90 calibration.

• HP3400 True RMS Voltmeter and standard 300 ohm dummy load. *Note: This equipment can be replaced with a standard ESU tester if available.*	• Potentiometer adjustment tool
• Clip Leads approximately 12" in length. Various types, banana jack and minigrabber style.	• Function generator capable of generating at least 500 kHz sine wave at 15Vp-p
• 150-300 ohm calibration load for adjusting the DAM circuit	• Frequency counter capable of measuring a 1 MHz TTL square wave.
• Oscilloscope with Tektronix P6130 test probe, or equivalent •	•

6.3 Setup

If the case top is installed on the LM-90 ESU, remove is before continuing. Position the LM-90 so that the front of the ESU is facing right and the Power Amplifier board is visible. During this test all adjustments for calibrating the LM-90 will be made to this board. Caution: This device is capable of producing DANGEROUS VOLTAGES and CURRENTS, be careful when working on any part of the unit.

6.4 Oscillator Adjustment

Its is imperative to adjust the oscillator frequency prior to delivering power to a calibration load. This is because the output stage of the amplifier is tuned to a specific frequency. A poorly adjusted oscillator frequency will cause low power delivery and heating and possible damage to the output stage.

U101, a switch mode power supply IC , runs in the following mode. There are 2 outputs which can be used to drive a push-pull arrangement. When one output is high (on) the other output is low(off). There is also a dwell time when both outputs are low (i.e. N channel output devices are both turned off). To accomplish the generation of this type of waveform the master oscillator runs at twice the output frequency. This is because the master oscillator clocks a flip-flop to generate the output control bits.

Oscillator Adjustment

- Make sure the AC power cord is connected to LM-90. The correct AC setting (110V or 220V operation) must be selected.
- Connect the return electrode or the 150-300 Ω calibration load to front panel return electrode connector. This will prevent the DAM (Dispersive Alarm Monitor) alarm from sounding during the initial calibration tests. *An alternative method of disabling the alarm tone is to*

disconnect the speaker connector form the controller board. If this method is used, be sure to reconnect the speaker prior to installing the LM-90 lid.

- Apply power to the ESU via the main power switch on the rear panel of the LM-90.
- Connect a frequency counter to TP101 at the output of U102-5 and 7.
- Adjust potentiometer R118 until the clock frequency is between 890 and 910kHz.

6.5 DAM Oscillator

The oscillator circuit uses a 555 timer for its frequency source. Its output plays into T103's primary and produces a tuned circuit with C111 and C112. A null will be produced at TP102 when the two return electrodes are shorted together.

Oscillator Adjustment

- Install a banana jumper between the two return electrodes. This will short transformer T103 secondary.
- Place an oscilloscope at TP102. This is used to measure the output NULL in the following step.
- Adjust R120 for maximum null. The frequency is unimportant but should be near 50 kHz (+/- 20kHz). If the frequency is 2 or 3 times that amount the null is probably adjusted for the 2nd or 3rd harmonic of the resonant circuit. The circuit will not function properly if not adjusted to the fundamental frequency.
- Remove the short between the two return electrodes.

6.5.1 DAM Comparator

A current is developed through R122 based on the resistance between the two return electrodes. This produces a voltage at TP102. The set point can then be adjusted by R126.

DAM Setpoint Adjustment

- Install the 150-300 Ω calibration load to the two return electrodes. Adjust the calibration load to its maximum value (greater than 300 ohms).
- Attach an oscilloscope to the output of comparator U105A-1. This will be used to measure whether the DAM is active or not.
- Adjust the calibration load for 300 Ω. U105-1 should go high at this point. Adjust R126 until the comparator switches high.
- Adjust the calibration load for its maximum value. U105-1 should go low.
- Adjust the calibration load for 300 Ω while watching the oscilloscope. U105-1 should just go high when the calibration load reaches 300 Ω.

6.6 Multiplier Offset Adjustment

6.6.1 Voltage Adjustment

- Ground the current channel by shorting JP110's pins together.
- Adjust the function generator for 450 kHz 10Vp-p square wave.
- Apply function generator to JP108 insuring the ground of the function generator goes to pin 2 of JP108 and that the output of the function generator goes to pin 1 of JP108.

- Place an oscilloscope on TP104. This test point only takes the special Tektronix "small" probe. A very high precision measurement can be done using this test point.
- Adjust R172 for minimum output at TP104.
- Remove function generator from circuit.
- Remove the shorting connector form circuit.

6.7 Current Adjustment

- Ground the voltage channel by shorting JP108's pins together.
- Adjust the function generator for 450 kHz 10Vp-p square wave.
- Apply function generator to JP110 insuring the ground lead goes to pin 2 and the output of the function generator goes to pin 1 of JP110.
- Place an oscilloscope on TP104.
- Adjust R170 for minimum output at TP104.
- Remove function generator from circuit.
- Remove shorting connector from circuit.

6.8 Output Adjustment

To calibrate the system there is only one set of adjustments used by all five modes of operation. This can be done because we are controlling power not currents or voltages. All 5 modes deliver power to a given load. They just do so by applying more or fewer pulses. The fewer the pulses the more the current. The only adjustment necessary then are to adjust the slope and intercept of the control voltage. This allows exact calibration of the output. Additionally, because COAG modes only deliver 2/3's the power of the CUT modes, a COAG set point adjustment is needed to calibrate their operating point.

The following section contain instruction to "calculate power." This means: measure the output voltage (VACrms) and calculate the power by dividing the square of that value by 300 (the load resistance). Alternatively, if an ESU Tester is used, read the power indication directly from its display.

6.8.1 Power Setpoint (slope adjustment)

- Install 300Ω, 200 watt non-inductive load to output of the ESU. Alternatively, install the ESU tester to the LM-90's output and insure the load is set for 300 ohms.
- Adjust CUT Select switch for PURE CUT.
- Adjust CUT set point control to full clockwise position. The display should read 120 watts.
- Apply power to the load briefly in PURE CUT mode. Measure the output power.
- Adjust R114 until the ESU produces 120 watts in PURE CUT mode.

6.8.2 Zero Setpoint (Intercept adjustment)

- Adjust the CUT set point control for a reading of 10 watts.
- Set the CUT select switch for PURE CUT.
- The 300 ohm test load should remain connected at this time.
- Apply power to the load briefly in PURE CUT mode. Measure the output power.
- Adjust R177 until the ESU produces 10 watts in PURE CUT mode.

- Adjust the CUT set point control for a reading of 120.
- Recheck the 120 watt output in PURE CUT mode. Some minor adjust may be required to trim the output.
- Recheck the 10 watt set point and adjust R177 as required.

6.8.3 Coag Adjustment

K103 and R116 and R155 form a current divider which shunts current away from summing junction U103-6 and its virtual ground. The values of R116 and R155 have been selected to shunt approximately 1/3 the current away from the summing junction. Therefore, only 2/3 the output control voltage is available at the summing function. The adjustment of R155 then calibrates the COAG output power to the display set point reading on the front panel.

- Set the COAG select switch to COAG 1.
- Adjust the COAG set point for a reading of 80 watts.
- Assure 300 ohm test load is connected to output.
- Apply power to the load briefly in COAG 1 mode. Measure the output power.
- Adjust R155 until the ESU produces 80 watts in COAG 1 mode.
- This completes the calibration of the LM-90 ESU.
- Turn off power and remove calibration loads from the ESU.

7. System Configuration Plan

This document describes current revision levels and configuration options of the LM-90 ESU.

7.1 Erasable Programmable Logic Device (EPLD)

Location	Controller board
Revision Level	1.10
Component Designator	U201

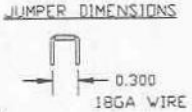
7.2 Schematic Revision Levels

Description	Revision Level
Controller	A
Power Amplifier	A
Power Supply	A

7.3 Printed Circuit Board Revision Level

Description	Revision Level
Controller	A
Power Amplifier	A
Power Supply	A

7.4 A.C. Line Voltage Configuration



CAUTION:
INSTALL JUMPERS FOR EITHER
220/240 VAC OPERATION
OR
110/120 VAC OPERATION
ONLY!

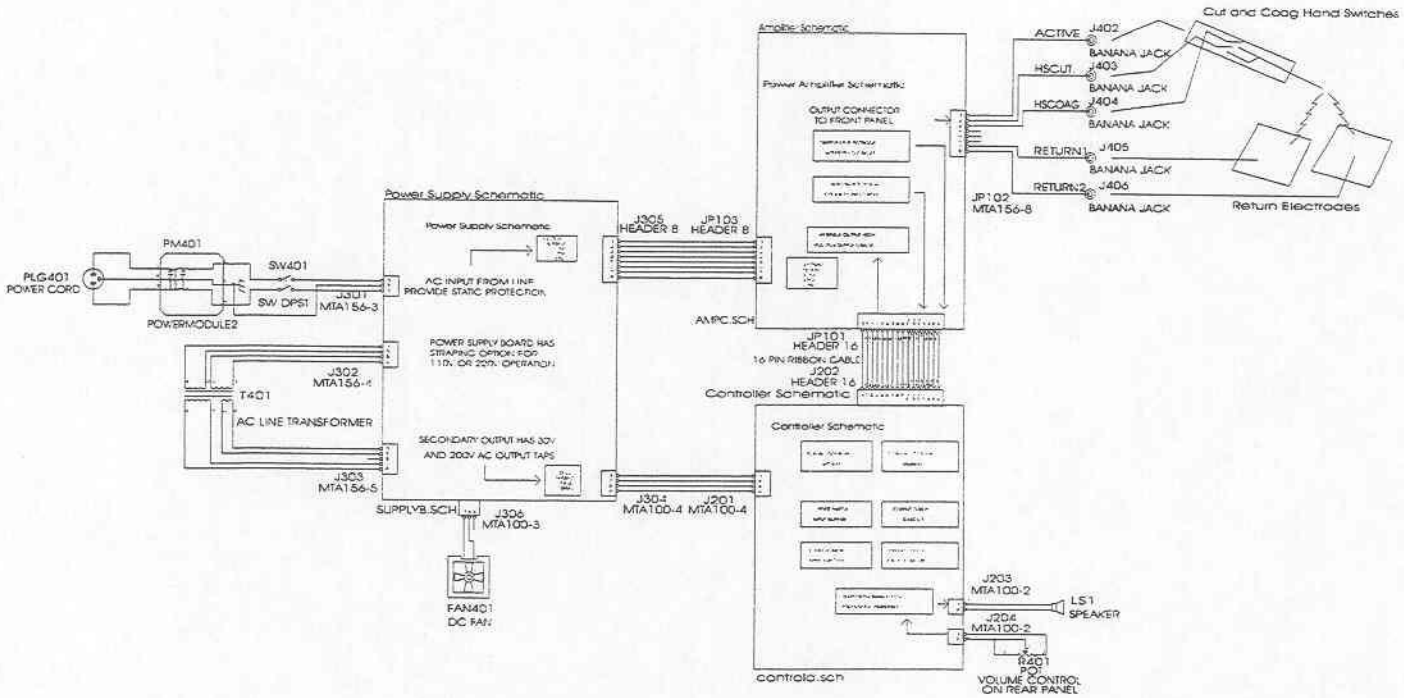
The input line voltage is jumper Selectable on the power supply board. Two input possibilities exist: 110Vac 60Hz; 220Vac 50Hz. Jumpers and fuses are to be installed in accordance with the following:.

Operation	Install Jumper(s)	Fuse
220/240 Vac	JP303	1.5 Amp
110/120Vac	JP301 & JP302	3.0 Amp

Both sides of the power cord line are fused. *Use slo-blo MDL 5 x 20mm fuses. Do not substitute. Higher amperage fuses may cause damage to unit or personnel.*

7.5 Circuit Interconnections

Following is an overall wiring diagram of the LM-90.



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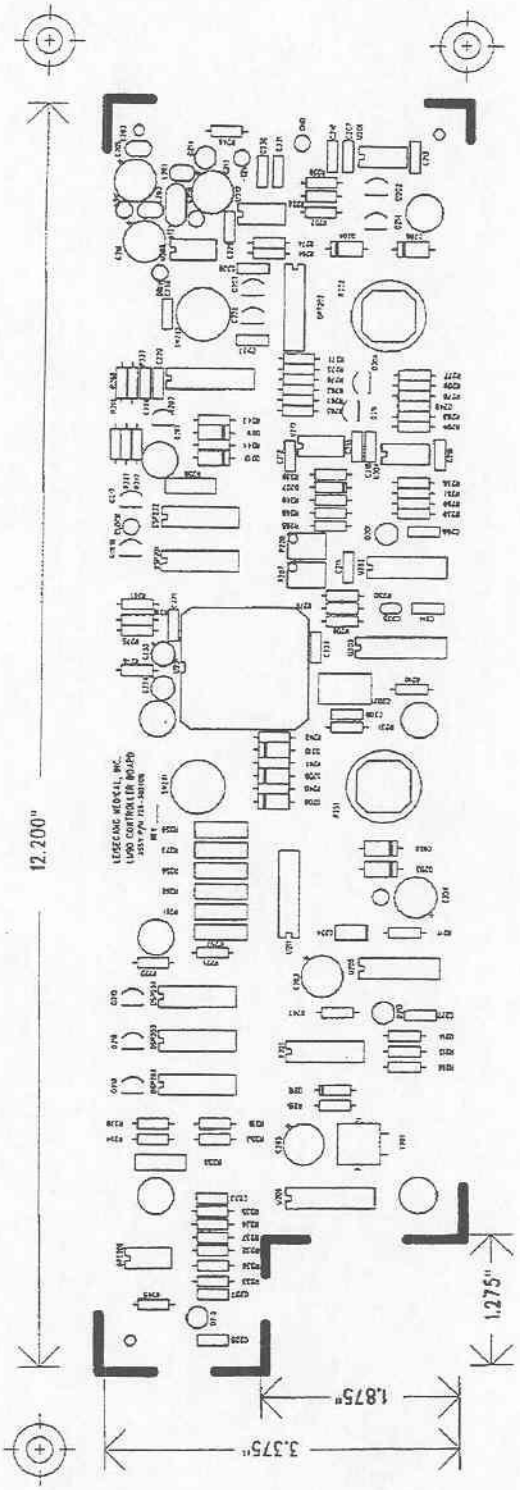
8. BILL OF MATERIALS AND COMPONENT LAYOUT

8.1 ESU BILL OF MATERIAL

Item	Qty	Reference	Part
1	1		A/C CONNECTOR WITH LINE FILTER
2	2		.925 KNOB
3	3		.50 KNOB
4	3		ROCKER SWITCH
5	20		CONTROLLER BOARD
6	1		POWER BOARD
7	1		POWER SUPPLY BOARD
8	2	J304-J201	CONNECTOR SUB ASSEMBLY
9	4	J301- POWER SUPPLY	CONNECTOR SUB ASSEMBLY
10	1		SPEAKER SUB ASSEMBLY
11	1		FAN SUB ASSEMBLY
12	1		RIBBON CONNECTOR SUB ASSEMBLY
13	4		TRANSFORMER SUB ASSEMBLY
14	2		VOLUME CONNECTOR SUB ASSEMBLY
15	5		ACTIVE/DISPERSIVE SUB ASSEMBLY
16	1	JP305-JP103	CONNECTOR SUB ASSEMBLY
17	1		BOARD HOLDER
18	1		CHASSIS
19	1		COVER
20	1		ESU OVERLAY
21	1		FOOTSWITCH SUB ASSEMBLY
22	1		PS TO PM SUB ASSEMBLY
23	1	J301 TO PS	CONNECTOR SUB ASSEMBLY
24	2		INSERT MOUNTING CLIP

8.1.1 Controller Board

8.1.1.1 Controller Board Layout



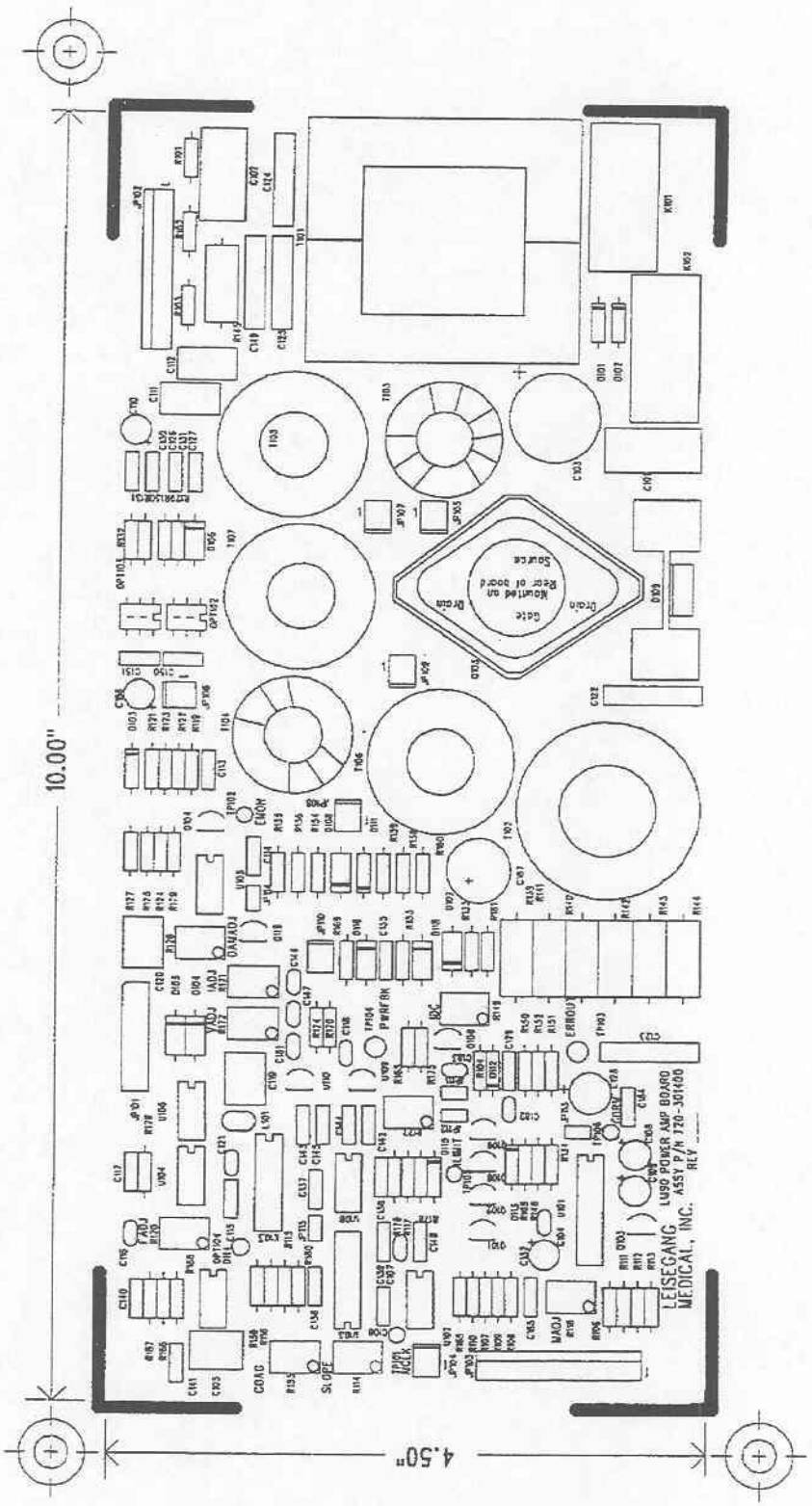
8.1.1.2 Controller Board Bill of Material

Item	Qty	Reference	Part
1	3	C201,C216,C217	100µF /16V
2	2	C202,C206	1 µF 50V FILM
3	3	C203,C204,C205	470µF /16V
4	3	C207,C224,C230	.1 µF
5	20	C208 -C215, C218-C221,C223,C225-C229,C231,C232,C236-C240	.47µF
6	1	C222	.01µF
7	1	C235	100Pf
8	2	C233,C234	1µF/50V CAP
9	4	DSP201,DSP202,DSP203,DSP204	7 SEGMENT DISPLAY
10	1	DSP205	7 SEGMENT DISPLAY
11	1	D201	T1-3/4,BLUE COAG
12	1	D202	VOLTAGE REF
13	4	D203,D204,D205,D206	DIODE
14	2	D207,D216	1N4148
15	5	D208-D212	ZENER 5.1V
16	1	D213	T1-3/4,AMBER,CUT
17	1	D214	T1-3/4,RED, ERROR
18	1	D215	T13/4,GREEN, SYSTEM ON
19	1	J201HEADER 4PIN .100 MTA	
20	1	J202	HEADER 16
21	1	J203	HEADER 2PIN .100MTA LCK
22	2	J204,J204	HEADER 3PIN .100MTA
23	1	OPT201	OPTO ISOLATOR
24	2	Q202,Q203	TRANSISTOR
25	2	Q201,Q210	TRANSISTOR
26	7	Q204-Q209,Q211	TRANSISTOR
27	2	R203,R204	511Ω
28	15	R201,R202,R205,R206,218,R220,R222,R234,R235,R254,R262-R264,R267,R268	2.21K Ω

29	4	R230,R231,R280,R281	10K Ω
30	2	R207,R208	1K Ω POT
31	1	R210	402K Ω
32	1	R211	2.7 Ω
33	2	R251,R252	1K/AUDIO POT PC MOUNT
34	6	R213,R215,R227,R249, R265,RR276	475 Ω
35	1	R214	100 Ω
36	16	R209,R216,R217,R219,R221,R225, R228,R229,R238,R253,R266,R270, R275,R276,R271,R279	1K Ω
37	5	R240-R244	4.75K Ω
38	1	R274	1.5K Ω
39	2	R232,R233	2K Ω
40	7	R236.R237,R245-R248,R250	
41	1	R239	1M Ω
42	8	R223,R255-R261	33 Ω .5W
43	1	R275	10 Ω
44	1	SW201	SWITCH
45	1	SW202	SWITCH
46	1	U201	EPLD
47	1	U202	QUAD OP AMP
48	1	U203	MULTIPLEXER
49	1	U204	OP AMP
50	1	U205	2W AUDIO AMP
51	1	U206	DTMF
52	2	U207,U211	HEX DIGIT DRIVER
53	1	U208	FET DRIVER

8.1.2 Power Amplifier Board

8.1.2.1 Power Amplifier layout



8.1.2.2 Power Amplifier Bill of Material

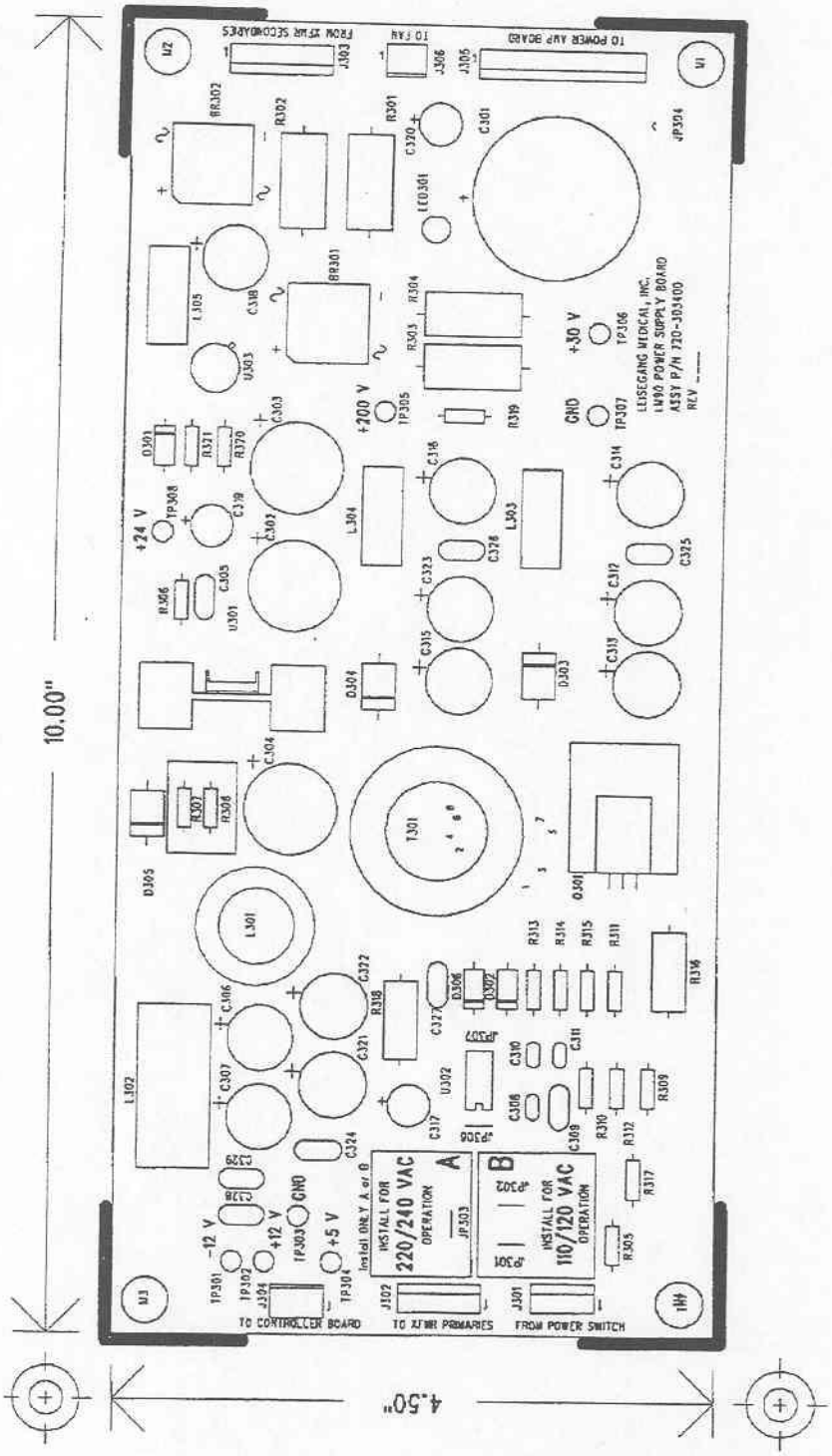
Item	Qty	Reference	Part
1.	2	C101,C102	10,000pF 1000V MICA
2.	1	C103	100/250V
3.	1	C104	1000pF
4.	3	C105,C119,C120	1 µF 50V FILM
5.	23	C106,C113-C115,C117, C126, C127, C129,C131,C136- C145, C148,C184,C185	.47
6.	5	C107,C146,C147,C150,C151	.1
7.	5	C108-C110, C132,C186	10/50V
8.	2	C111,C112	0.1 250VDC
9.	1	C116	0.022
10.	4	C118,C181,C182,C183	0.001
11.	1	D121	100pF
12.	1	D135	330pF
13.	3	D124,D125,D149	220pF 1500V MICA
14.	2	D122,D123	100pF 1500V MICA
15.	1	C128	100/50V
16.	1	D101-D103,D111,D112	470µF/25V
17.	7	D113,D115	DIODE
18.	7	D104-D108,D116,D118	DIODE
19.	1	D109	DIODE, DUAL
20.	1	D114	LED T1 YELLOW
21.	1	D119	VOLTAGE REF
22.	1	JP101	HEADER 16
23.	1	JP102,JP103	HEADER 8PIN .156MTA
24.	7	JP104-JP110	HEADER 2PIN .100MTA
25.	5	JP111-JP115	HEADER 2 PIN .100 MTS
26.	2	K101,K102	RELAY
27.	1	K103	RELAY
28.	1	L101	#75 BEAD
29.	1	OPT104	OPTO ISOLATOR
30.	2	OPT102-OPT104	OPTO ISOLATOR

31.	1	Q101	TRANSISTOR
32.	4	Q102,Q104,Q108,Q109	TRANSISTOR
33.	2	Q103,Q106	TRANSISTOR
34.	1	Q105	TRANSISTOR
35.	1	R150	499
36.	4	R101-R103,R125	1M
37.	2	R148,R104	6.81K
38.	11	R105,R110,R117,R124,R129, R131,R166-R168,R175,R178	1K
39.	2	R107,R127	475
40.	8	R108,R113,R115,R1169,R122, R156,R169,R180	100
41.	1	R149	100POT TOP ADJ
42.	1	R109	22.1
43.	3	R111,R112,R159	2K POT TOP ADJ
44.	4	R130,R132,R160,R165	392
45.	4	SR128,R133,R151,R176	200
46.	3	R118,R120,R126	33.2K
47.	6	R119,R121,R123,R134,R152,R179,R181	300,1W
48.	1	R177	1000, 1W
49.	1	R114	2.49K
50.	1	R106	50 POT TOP ADJ
51.	2	R135,R136	15K
52.	3	R153,R170,R174	2.43
53.	6	R139,R140-R144	100K POT ADJ
54.	1	R145	TEST POINT, BLUE
55.	1	R154	PROBE TEST POINT
56.	1	R155	XFMR OUTPUT
57.	1	R158	XFMR DRIVER 36:36
58.	1	R163	XFMR DAM 40:15
59.	2	R171,R172	XFMR SW SUPPLY 15:15
60.	4	TP101,TP102,TP105,TP106	XFMR CURRENT 2:100
61.	2	TP104,TP103	XFMR CURRENT LIM 1:100

62.	1	T101	XFMR VOLTAGE 200:1
63.	1	T102	SWITCHER
64.	1	T102	FET DRIVER
65.	1	T103	OP AMP
66.	1	T104	TIMER
67.	1	T105	COMPARITOR
68.	1	T106	MULTIPLIER
69.	1	T107	REGULATOR +5V 100Ma
70.	2	U101	REGULATOR -5V 100Ma
71.	1	U102,U106	SHORTING JUMPER
72.	1	U103	INSULATING COLLAR
73.	1	U104	SIL-PAD TO-220
74.	1	U105	SCREW SKT HD 4-40 X ¼
75.	1	U108	NUT 4-40X ¼ KEPS
76.	1	U109	HEAT SINK TO-220
77.	5	U110	SCREW PAN HD 6-32X5/8
78.	1	JP111,JP112,JP113,JP114,JP115	SIL-PAD TO-3P
79.	1	D109	WASHER LOCK #6
80.	1	D109	NUT #6
81.	1	D109	HEAT SINK TO-3 3"
82.	1	D109	TRANSISTOR INSULATOR
83.	2	D109	JUMPER CABLE
84.	1	Q105	PCB
85.	2	Q105	4.75K Ω
86.	2	Q105	1.5K Ω
87.	1	Q105	2K Ω
88.	1	Q105	TRANSISTOR INSULATOR
89.	3		JUMPER CABLE
90.	1		PCB

8.1.3 Power Supply Board

8.1.3.1 Power Supply Component Layout



8.1.3.2 Power Supply Bill of Materials

Item	Qty	Reference	Part
1.	2	BR301, BR302	BRIDGE RECTIFIER
2.	1	C301	1000 µF/250V
3.	3	C302-C304	1000 µF/50V
4.	1	C320	100 µF/50V
5.	6	C305	.01µF
6.	1	C324-C329	.47µF
7.	10	C309	470µF/25V
8.	1	C306,C307,C312-C316,C321-C323	470µF/50V
9.	1	C318	100pF
10.	1	C308,C310,C311	10µF/50V
11.	2	C317,C319	DIODE
12.	1	D301	DIODE
13.	1	D302	FAST RECOVERY RECTIFIER
14.	2	D303,D304	SCHOTTKY DIODE, 3AMP
15.	1	C305	18V ZENER DIODE
16.	1	D306	JUMPER .3"
17.	1	JP301,JP302,JP303	MTA156-3
18.	1	J301	MTA156-4
19.	1	J302	MTA156-5
20.	1	J303	MTA156-8
21.	1	J305	MTA100-3
22.	1	J306	MTA100-4
23.	1	J304	RED T1 ¾
24.	1	LED301	100 µH
25.	1	L301	FET
26.	1	L302	.1Ω 2W
27.	3	L303,L304,L305	10K 2W
28.	1	Q301	5.1M
29.	2	R301, R302	2.74K
30.	2	R303,R304	10

31.	2	R305,R317	2.80K
32.	1	R306	2.21K
33.	1	R307	2K
34.		R307	15K
35.		R308	511
36.	1	R309	10K
37.	1	R310	22.1
38.	1	R311	1K
39.	1	R312	20K
40.	1	R313	.33Ω 1W
41.	2	R314,R319	470 Ω 1W
42.	1	R315	4.32
43.	1	R316	240
44.	1	R318	
45.	1	R320	
46.		R321	240
47.	1	T301	FLYBACK TRANSFORMER
48.	1	U301	SWITCHNIG REGULATOR
49.	8	U301	SWITCHNIG REGULATOR
50.	1	U302	SWITCHER
51.	1	U303	REGULATOR
52.	8	TP301,TP102-TP108	TEST POINT, RED
53.	1	LM90 PS REV A	PC BOARD
54.			